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REMARKS

Claims 1-13, 17-23, 27-29, 34-47, 50-55, and 59-63 are pending in the subject application. Claims 1 and 50 have been amended and claims 23 and 55 have been cancelled. Applicants expressly reserve their right to pursue the subject matter of the cancelled claims in this or a co-pending application. Support for the amendment to claims 1 and 50 may be found in claims 23 and 55 as originally filed.

Favorable reconsideration in light of the amendments and remarks which follow is respectfully requested.

1. 35 U.S.C. §112 Rejections

Claims 1-13, 17-23, 27-29, 34-47, 50-55 and 59-63 are rejected under 35 U.S.C. §112, second paragraph, as being indefinite. The Office states that:

The Examiner has maintained the assertion that the subject matter encompassed by the terms "low polarity block" or "low polarity oligomeric block" is unclear.

Applicants respectfully disagree the term "low polarity block" is clearly understood in the adhesive and polymer fields. Enclosed are excerpts from Introduction to Physical Polymer Science and Polymer Handbook, 4th ed, which teach that low surface energy materials possess high adhesive properties and that surface energy is proportional to the polarity of the material. Thus, low polarity materials, e.g., materials with low dipolar interactions, have low surface energy and increased adhesion to surfaces.

Introduction to Physical Polymer Science teaches, at page 562, that amorphous polymers have lower density and a lower surface tension than crystalline materials. Furthermore, the enclosed tables from Polymer Handbook illustrates that materials suitable for use as low polarity blocks in the coating compositions of the present invention, e.g., siloxanes, polyolefins,

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fluoropolymers, ABA block copolymers and the like, have low polarity (χ^P) values compared to other materials.

Polarity of a material may be defined by cohesive energy density. See, Polymer Handbook, page IV/523. The polarity of a polymer is directly proportional to a polar function arising from dipolar interactions and the surface free energy (surface tension) is proportional to the polarity of the material. Thus low polarity materials, such as those low polarity blocks provided by claim 1 and 50, have low surface tensions and provide increased surface wetting and adhesion to substrates.

Thus the term "low polarity block" is well understood by one skilled in the art to refer to a block having low polarity, e.g., a block having low dipolar interactions. Moreover, one skilled in the art understands that such low polarity blocks have low surface energy, are suitable for wetting surfaces and providing increased adhesion to a surface.

Applicants believe that claims 1-13, 17-23, 27-29, 34-47, 50-55 and 59-63 meet all the requirements under 35 U.S.C. §112 including the requirements of §112, second paragraph. Thus the rejection of claims 1-13, 17-23, 27-29, 34-47, 50-55 and 59-63 should be withdrawn.

2. 35 U.S.C. §102/103 Rejections

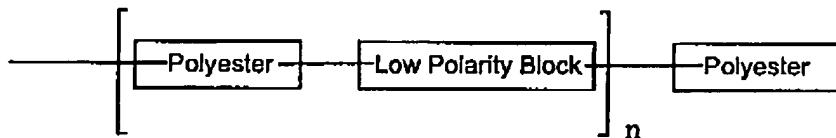
A brief description of the present invention may be of assistance in addressing the 102/103 rejections presented in the outstanding office action.

As provided by claim 50, the present invention provides adhesive or coating copolyester compositions having substantial adhesion, e.g., improved adhesion, where the composition comprises the reaction product of at least one difunctional alcohol, at least one dicarboxylic acid, and at least one low polarity telechelic oligomeric block material.

As is well known in the art, a difunctional alcohol and a dicarboxylic acid react to form a polyester through a dehydration-esterification process. Telechelic low polarity oligomeric

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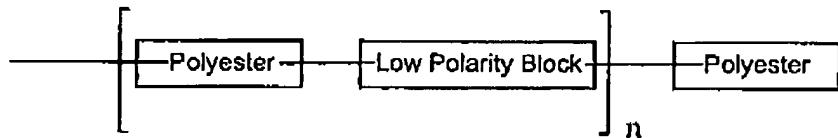
blocks have functional groups suitable for coupling with either a carboxylate residue or an alcohol at the termini of the main chain of the oligomer such that the low polarity block may be imbued into the growing main chain of the polyester to form a block copolymer structure which may be represented by the generic structure:



wherein n is a positive integer.

As provided by claim 50 and by the specification, telechelic low polarity blocks suitable for use in the compositions of the present invention include: (1) saturated and unsaturated telechelic polyolefins having a weight average molecular weight of between about 500 and 4500, (2) ABA block copolymers where B is an alkyl and/or aromatic substituted polysiloxane, and where A is a functionally terminated polyalkyleneoxide, (3) telechelic fluoropolymers. See, for example, page 6, line 22 to page 7, line 14.

The invention further provides methods of improving adhesion of copolymers by incorporating a low polarity telechelic oligomeric block segment into the copolymer polymer chain (see claim 1). Incorporation of telechelic oligomeric block segment into a copolymer polymer results in formation of a block copolymer of the generic formula above, e.g., a block copolymer of the formula:



wherein n is a positive integer.

The invention further provides methods of making an adhesive or coating, comprising reacting at least one difunctional alcohol and at least one dicarboxylic acid to form a copolymer polymer chain; and infusing at least one low polarity polymeric block into the copolymer polymer chain during the formation of the copolymer polymer chain.

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Claims 1-12, 17-22, 35-47, 50-54 and 60-63 have been rejected under 35 U.S.C. §102(b) as anticipated by or, in the alternative, under 35 U.S.C. §103(a) as obvious over Lin.

Claims 1-13, 17, 20-22, 37-47, 50-53 and 60-63 have been rejected under 35 U.S.C. §102(b) as anticipated by or, in the alternative, under 35 U.S.C. §103(a) as obvious over Policastro.

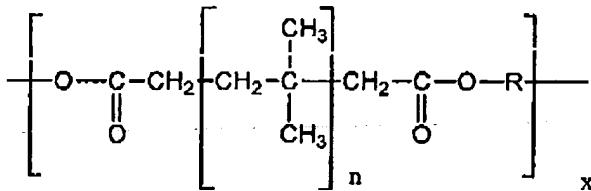
Claims 37-47, 50-54 and 62 are rejected under 35 U.S.C. 102(b) as anticipated by or, in the alternative, under 35 U.S.C. §103(a) as obvious over each of Hallgren and Eichenauer.

The language of claim 23 has been incorporated into claim 1 and the language of claim 55 has been incorporated into claim 50. The Examiner has indicated in the Office Actions of January 30, 2002 and September 24, 2002 that Claims 23 and 55 were neither anticipated nor obvious in view of Lin, Policastro, Hallgren, Eichenauer, or any combination thereof. Thus, claims 1 and 50 as amended are also patentable over Lin, Policastro, Hallgren, Eichenauer, or any combination thereof. Claims 2-13, 17-22, 27-29, 34-47, 51-54, and 59-63 depend from claims 1 and 50 and are therefore also patentable over Lin, Policastro, Hallgren, Eichenauer, or any combination thereof.

Claims 1-13, 17-23, 37-47, 50-53 and 60-64 have been rejected under 35 U.S.C. §102(b) as anticipated by or, in the alternative, under 35 U.S.C. §103(a) as obvious over Peters '158.

As the reference is understood, Peters does not teach block copolymers composed of polyester blocks and polyisobutylene blocks. More particularly, Peters appears to teach a polycarbonate comprising as the diacid monomer a carboxylate terminated polyisobutylene oligomer. Thus the polyesters taught by Peters comprise alternating (cyclo)alkylene diol and polyisobutylene groups linked by ester bonds, i.e., Peters teaches polymers of the general formula:

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where n is an integer suitable for making the polyisobutylene block have a Mw of between 5,000 and 30,000 and R is a linear alkylene or a cycloalkylene diradical.

In other words, Peters provides a polyester composed of a diol (HO-R-OH) and a diacid where the diacid is a carboxylic acid terminated polyisobutylene according to Formula III. More particularly, Peters appears to teach polyisobutylene blocks linked to an aliphatic or cycloaliphatic diol through two ester bonds. Thus, Peters neither discloses nor suggests block copolymers having polyester blocks and polyolefin blocks.

Peters neither teaches nor discloses the polyester resins of the present invention. That is, Peters neither teaches nor discloses resins having polyester resins having both polyester blocks and low polarity blocks present in the resin. Moreover, Peters does not teach polyester resins having at least one low polarity polymeric block is selected from the group of: saturated and unsaturated telechelic polyolefins, fluorine substituted telechelic oligomers and polymers, functionally terminated ABA block copolymers of polyalkylencoxide (A) and alkyl and aromatic substituted polysiloxanes (B), and blends thereof.

Thus claims 1 and 50 are patentable over Peters. Claims 2-13, 17-23, 27-29, 34-47, 51-55 and 59-63 are dependent from either claim 1 or claim 50 and are therefore also patentable over Peters.

Reconsideration and allowance of claims 1-13, 17-23, 27-29, 34-47, 50-55 and 59-63 is respectfully requested in view of the foregoing discussion. This case is believed to be in condition for immediate allowance. Applicant respectfully requests early consideration and allowance of the subject application.

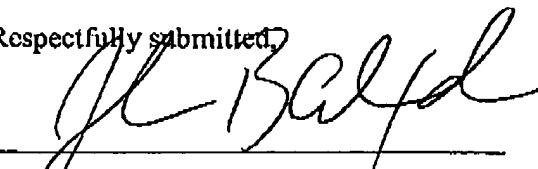
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If for any reason a fee is required, a fee paid is inadequate or credit is owed for any excess fee paid, you are hereby authorized and requested to charge Deposit Account No. 04-1105.

Should the Examiner wish to discuss any of the amendments and/or remarks made herein, the undersigned attorney would appreciate the opportunity to do so.

Respectfully submitted,

Date: December 24, 2002


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VERSION WITH MARKINGS TO SHOW CHANGES MADE IN CLAIMS

Please note that additions to the claims are shown underlined and deletions are shown in brackets.

Please cancel claims 23 and 55 without prejudice or disclaimer.

Kindly amend claims 1, 8-12 and 50-51, as follows:

1. (amended) A method of making an adhesive or coating, comprising:
reacting at least one difunctional alcohol and at least one dicarboxylic acid to form a copolyester polymer chain, and
during the course of that reaction, infusing at least one low polarity polymeric block into the copolyester polymer chain wherein at least one low polarity polymeric block is selected from the group of: saturated and unsaturated telechelic polyolefins, fluorine substituted telechelic oligomers and polymers, functionally terminated ABA block copolymers of polyalkyleneoxide (A) and alkyl and aromatic substituted polysiloxanes (B), and blends thereof.
8. (amended) The method of claim 1, whereby the adhesive or coating has [substantial]improved adhesion to polymeric or cellulosic substrates.
9. (amended) The method of claim 8, whereby the [substantial]improved adhesion is initial adhesion.
10. (amended) The method of claim 9, whereby the [substantial]improved adhesion is initial adhesion to low surface energy substrates.
11. (amended) The method of claim 8, whereby the [substantial]improved adhesion is aged adhesion.

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12. (amended) The method of claim 11, whereby the [substantial]improved adhesion is aged adhesion to low surface energy substrates.

50. (amended) An adhesive or coating copolyester composition having substantial adhesion to polymeric substrates, comprising the reaction product of:

at least one difunctional alcohol;

at least one dicarboxylic acid; and

at least one low polarity telechelic oligomeric block material wherein at least one low polarity block is selected from the group of: saturated and unsaturated telechelic polyolefins; fluorine substituted telechelic oligomers and polymers; functionally terminated ABA block copolymers of (A) polyalkyleneoxide and (B) alkyl or aromatic substituted polysiloxanes; and blends thereof.

51. (amended) The adhesive or coating composition of claim 50, wherein the composition has [substantial]improved retained adhesion to polymeric and low surface energy substrates.

Kindly cancel claims 23 and 55 without prejudice or disclaimer.

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**INTRODUCTION
TO PHYSICAL
POLYMER SCIENCE**

SECOND EDITION

L. H. Sperling
Lehigh University
Bethlehem, Pennsylvania



A WILEY-INTERSCIENCE PUBLICATION

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P. 03

This book is dedicated to my grandsons, Ryland Everett Sweigard, October 13, 1988, and Tressen Andriessen Sweigard, born February 1991. They think that plastics are to play with.

In recognition of the importance of preserving what has been written, it is a policy of John Wiley & Sons, Inc. to have books of enduring value published in the United States printed on acid-free paper, and we exert our best efforts to that end.

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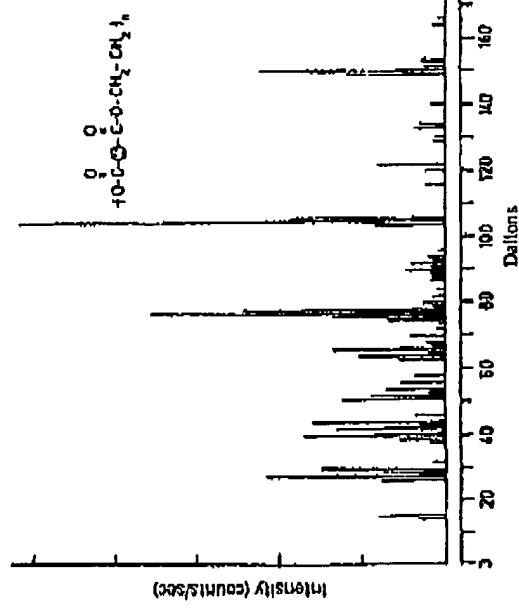


Figure 12.1 Positive SIMS of poly(ethylene terephthalate) using 4-keV Ar+ (film sample). 10^3 counts / sec sec (4).

energizes several of the more important methods of polymer surfaces and interfaces. Electron spectroscopy, ESCA, also known as x-ray photoelectron analysis, is based on the observation that electrons are emitted by radiation. The energy of the emitted electrons yields the electron to the particular atom, which is the primary energy analyzer and counter. The method is used for measuring surface oxidation, surface strain, and a variety of lubrication problems.

Contact angle refers to the angle a drop of liquid makes where it meets the surface, Table 12.1. If it wets the surface, it will spread out, making a shallow angle. If it does not wet the surface, it may "bead up," the angle being larger than 90°.

12.1.2 Surface and Interfacial Tension

The free energy of formation of a surface is always positive, since work is required to create a new surface. This increases the total free energy of the system. The work, W , required to create a unit surface area, dA , is given by

$$W = \bar{\gamma} dA$$

which is another formulation of equation (11.34). The surface tension, $\bar{\gamma}$, has units of ergs/cm² or SI units of J/m². Since ergs, or work generally, can be expressed as force times distance, customary units are dynes/cm. Thus surfaces may be treated using either the concept of surface tension or the equivalent concept of surface free energy (G). Surface tension is the earlier of the two terms, going back to ideas that the surface of a liquid has some kind of contractile "skin." The term surface free energy implies that work is required to form more surface, involving the bringing up of more molecules from the interior of the substance, associating it more readily with conventional thermodynamic language. Thus the surface tension is actually the free

Second, the measurement problems have ...
or on the limitations of polymer surfaces and interfaces.
inter bleeding and miscibility (Section 5.4.4),
) and film formation from latexes (Section 5.4.4.2),
ways of characterizing polymer surfaces and interfaces.

Methods of Characterization

uses several of the more important methods of polymer surfaces and interfaces. Electron spectroscopy, ESCA, also known as x-ray photoelectron analysis, is based on the observation that electrons are emitted by radiation. The energy of the emitted electrons yields the electron to the particular atom, which is the primary energy analyzer and counter. The method is used for measuring surface oxidation, surface strain, and a variety of lubrication problems. Contact angle refers to the angle a drop of liquid makes where it meets the surface, Table 12.1. If it wets the surface, it will spread out, making a shallow angle. If it does not wet the surface, it may "bead up," the angle being larger than 90°.

uses a noble gas ion beam, e^+ , which is directed onto the sample surface (4). On surface material, molecular fragments consisting of one or uttered into a vacuum. These secondary ions are directed meter to provide, in sequential experiments, the positive mass spectra, respectively. For example, Figure 12.1 (4) IS spectra of poly(ethylene terephthalate). The protonated at 193 D (daltons, atomic mass units, g/mol), and peaks are present fragmentation with dominant peaks at 149 D $-CO^+$, 104 D $(C_6H_4CO_2^+)$, and 77 D $(C_6H_5^+)$. SIMS can detect the presence of dimethyl siloxane contamination on polymer. Auger spectroscopy, AFS, has an atom in an M^+ excited state ion to form an M^{++} lower lying state. Surface examination In this process, an electron beam gun fires electrons at a surface, which increases the interaction with surface atoms. number of emitted Auger electrons are detected by an

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Table 12.2 Interfacial tension between select polymer pairs (S)

Polymer	Interfacial Tension		$-(\bar{\gamma}_s/T)$ erg/cm ² /deg
	20°C	100°C	
PS/PDMS	6.1	6.1	0.008
PDMS/PEO	10.8	10.2	0.008
PS/PMMA	3.2	2.2	0.013

PS = polystyrene; PDMS = poly(dimethyl) siloxane;

PEO = poly(ethylene oxide); PMMA = poly(methyl methacrylate)

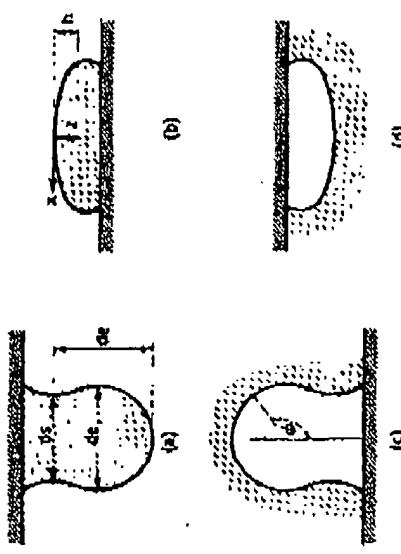
Source: S. Wu, *Polymer Interface and Adhesion*, Marcel Dekker, New York, 1982, p. 126.

Figure 12.2 The shape of drops and bubbles can be used to calculate the surface tension of polymer and other substances (5): (a) sessile drop, (b) hanging drop, (c) sessile bubble, (d) hanging bubble, (e) sessile bubble, and (f) sessile bubble.

energy per unit area. At constant volume, the entropy of surface formation per unit area is given by

$$\Delta S^\circ = -\frac{d\bar{\gamma}}{dT} \quad (12.2)$$

Methods of measuring the surface tension include the pendant drop method, the sessile drop method, and others (5-7). These methods depend on the shape of a drop of the polymer or bubble in it, and depend on the sum of surface tension and gravitational forces, see Figure 12.2 (5).

Some numerical values of $\bar{\gamma}$ and $d\bar{\gamma}/dT$ were shown in Table 11.6. Positive values of $-d\bar{\gamma}/dT$ mean an increase in the entropy on the formation of the surface. This may be associated with the highly irregular structure of the surface, with molecules or segments literally protruding into the air, or (as below) into another phase. This density gradient may be described in terms of fractals, see Section 11.5.5.

Surface tension is usually defined as involving a single phase in equilibrium with its vapor. In the case of a polymer, where the vapor pressure is substantially zero, the polymer is considered in contact with air.

When the polymer contacts a condensed phase, it is common to talk about the interfacial tension of the system. A special case of interest involves two polymers in contact. Interfacial tensions are shown in Table 12.2 (6) for a few selected polymer pairs. The low surface tension of poly(dimethyl siloxane), relative to almost all other polymers, favors spreading. In order for liquid *b* to spread over liquid *a*, it is necessary that the spreading coefficient,

$$\lambda_{a/b} = \bar{\gamma}_b - (\bar{\gamma}_a + \bar{\gamma}_{ab}) \quad (12.3)$$

$$|\bar{\gamma}_a - \bar{\gamma}_b| < \gamma_{ab}$$

neither liquid can spread on the other (8). Figure 12.3 (9) shows 1 concentrations of only about 1%, poly(dimethyl) siloxane) covers 50%; the surface of a block copolymerblend mixture with polycarbonate (11.6), this is to be expected. LeGrand and Gaines (11) found that the angles of all their blends of polycarbonate and poly(dimethyl siloxane) displayed contact angles very close to that of pure poly(dimethyl siloxane) providing important supporting information.

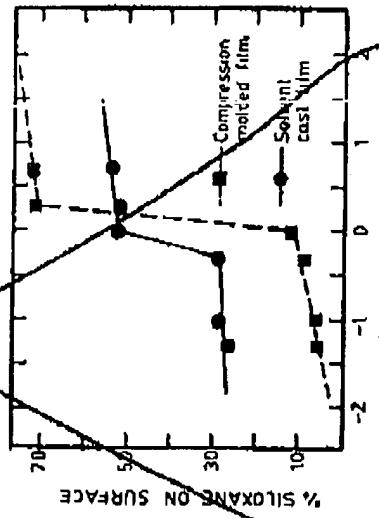


Figure 12.3 Surfaces by ESCA. Instrumentation reveals that surface segregation in block copolymerblend-polycarbonate-black-poly(dimethyl siloxane) segmented copolymer (9).

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Table 12.2 Interfacial tension between select polymer pairs (6)

Polymers	Interfacial Tension		$-(\frac{d\gamma}{dT})$ erg/cm ² - deg
	20°C erg/cm ²	100°C erg/cm ²	
PS/PDMS	6.1	6.1	0.008
PDMS/PEO	10.8	10.2	0.0078
PS/PMMA	3.2	22	0.013

PS = polystyrene; PDMS = poly(dimethyl siloxane);
PEO = poly(ethylene oxide); PMMA = polymethyl methacrylate)Source: S. Wu, *Polymer Interface and Adhesion*, Marcel Dekker, New York, 1982, p. 126.

of drops and bubbles can be used to calculate the surface tension: (a) hanging drop, (b) sessile drop, (c) drops and bubbles

At constant volume, the entropy of surface formation is given by

$$\Delta S^* = \frac{-d\gamma}{dT}$$

measuring the surface tension include the pendant drop method, and others (5-7). These methods depend on the density gradient, and gravitational forces; see Figure 12.2 (5). In the case of a polymer in contact with air, or in the case of a polymer, where the vapor pressure is low, the polymer is considered in contact with air. The polymer contacts a condensed phase, it is common to talk about the vapor pressure of the system. A special case of interest involves two molecules of segments literally protruding into the air, or another phase. This density gradient may be described in terms of the vapor pressure of the polymer, and the vapor pressure of the air. The low surface tension of poly(dimethyl siloxane), at all other polymers, favors spreading. In order for liquid to spread, it is necessary that the spreading coefficient, $\gamma_s - \gamma_b$, be positive. If

$$[\gamma_s - \gamma_b] < \gamma_{ab} \quad (12.4)$$

neither liquid can spread on the other (8). Figure 12.3 (9) shows that at concentrations of only about 1%, poly(dimethyl siloxane) covers 50-70% of the surface of a block copolymer-blend mixture with polycarbonate, as determined by ESCA. Noting the large difference in surface tensions (Table 11.6), this is to be expected. LeGrand and Games (10) found that the contact angles of all their blends of polycarbonate and poly(dimethyl siloxane), displayed contact angles very close to that of pure poly(dimethyl siloxane), providing important supporting information.

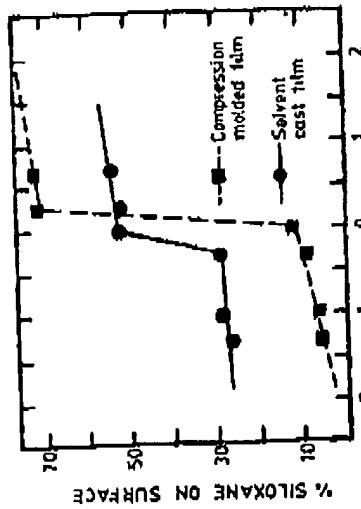


Figure 12.3 Studies by ESCA instrumentation reveal that surface segregation in polycarbonate-blend-polycarbonate-block-poly(dimethyl siloxane) segmented copolymer blends

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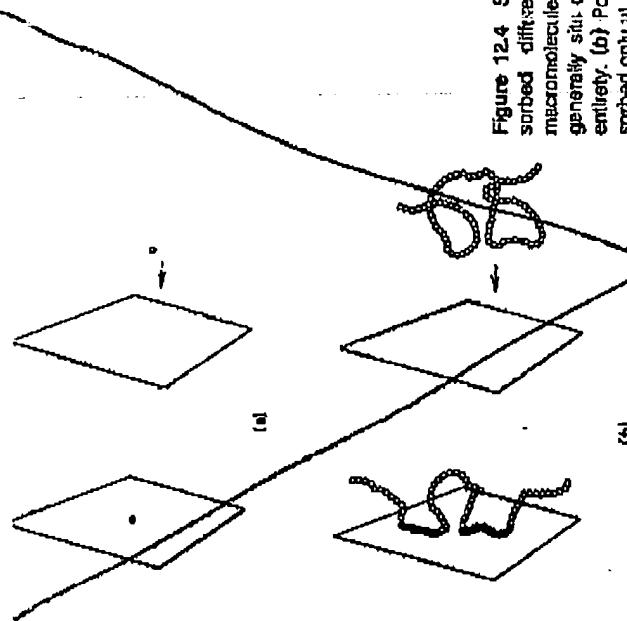


Figure 12.4 Small molecules sorbed differently than linear macromolecules (11). (a) A small linear macromolecule (11). (b) Polymer chains are sorbed only at one or more short segments.

The surface tension of a crystalline polymer can be approximately calculated from (6)

$$\bar{\gamma}_c/\bar{\gamma}_a = (\rho_c/\rho_a)^\pi \quad (12.5)$$

where π is about 4, ρ represents the density, and c and a represent crystalline and amorphous, respectively. Since the density of crystalline polymers is higher than that in the corresponding amorphous state, the surface tension is higher. For polymers undergoing the glass-rubber transition, the relationship can be written (6)

$$\left(\frac{d\bar{\gamma}}{dT}\right)_G = \frac{\alpha_G}{\alpha_R} \left(\frac{d\bar{\gamma}}{dT}\right)_R \quad (12.6)$$

where α represents the expansion coefficient. Since $\alpha_G < \alpha_R$, then

$$-\left(\frac{d\bar{\gamma}}{dT}\right)_G < -\left(\frac{d\bar{\gamma}}{dT}\right)_R \quad (12.6a)$$

While the surface tensions themselves are continuous across the transition, the temperature derivatives are not.

12.1.3 Polymers at an Interface

Consider the adsorption of a polymer on the surface of another substance; see Figure 12.4 (11). There are three parts to the adsorbed chain: the surface-held trains, the free-hanging loops, and the two tails, all in equilibrium. Where each mer in the surface-held trains may have only a small bonding energy, strong positive adsorption occurs, because many such bonds are formed. All must be released substantially simultaneously in order to debond the chain as a whole, creating low probabilities of desorption in many cases.

De Gennes pointed out that both attractive walls and repulsive walls must be considered (12). This is important if the polymer is in solution, and especially so if the surface prefers the solvent to the polymer. Figure 12.5 (12) illustrates the conditions at attractive versus repulsive walls. For the attractive wall situation, the concentration profile exhibits three regions: the proximal region, which is very sensitive to the details of the interactions, the central region, which exhibits self-similarity (see below), and the distal region, which is controlled by a few large loops and tails. Scaling analysis shows that the concentration, $\varphi(z)$, in the central region follows the relation-

ship between α and z ,

$$\varphi(z) = (\alpha/z)^{4/3}$$

where α represents the proximal distance (about the length of a mer), z is the distance from the wall. The total thickness of the interface is governed by the size of the polymer chains and may be hundreds of angstroms. The repulsive wall relationships are governed by the polymer chain translation length, ξ ; see Figure 12.5. Due to the decreases in entropy if the chain lies near the wall, the region next to the wall may contain nearly all segments. This is called the depletion layer.

There are several important experimental results that arise because of the repulsive wall problem:

1. The effective pore size in GPC particles is smaller than the actual size.
2. During polymerization of latexes, the portion of the latex near the surface may be enriched in monomer relative to the interior.
3. Reaction rates of polymers with surfaces may be reduced.
4. The surfaces of polymer solutions may be substantially denatured by the polymer.

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POLYMER HANDBOOK

FOURTH EDITION

Editors

J. BRANDRUP, E. H. IMMERMUT, and E. A. GRULKE

Associate Editors

**A. ABE
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Surface and Interfacial Tensions of Polymers, Oligomers, Plasticizers, and Organic Pigments

Souheng Wu

E. I. du Pont de Nemours & Company, Central Research and Development Department,
Experimental Station, Wilmington, Delaware, USA

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C. References

A. INTRODUCTION

1. Definition

The surface (interfacial) tension is the reversible work required to create a unit surface (interfacial) area at constant temperature (T), pressure (P), and composition (n) (1), i.e.,

$$\gamma = (\partial G / \partial A)_{T,P,n} \quad (A1)$$

where γ is the surface (interfacial) tension, G the Gibbs free energy of the system, and A the surface (interfacial) area.

P-559 *See Spelling. The surface tension is actually the free energy per unit area*

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The specific surface free energy f_s is the free energy per unit surface area (1), i.e.,

$$f_s = \gamma + (C_1\mu_1 + C_2\mu_2) \quad (A2)$$

where C_j is the surface concentration (the number of moles per unit area) of component j , and μ_j is the chemical potential of component j . Thus $\gamma = f_s - (C_1\mu_1 + C_2\mu_2)$, which means that the surface tension is the excess specific surface free energy. The excess means in excess of the bulk phase. This distinguishes the surface tension and the specific surface free energy (1).

2. Temperature Dependence

The surface tension of polymers, just as with small-molecule liquids, varies with temperature (1) by

$$\gamma = \gamma_0(1 - T/T_c)^{1/9} \quad (A3)$$

where γ_0 is the surface tension at $T=0$ K, and T_c is the critical temperature. The temperature coefficient of surface tension is thus given (1) by

$$-d\gamma/dT = (11/9)(\gamma_0/T_c)(1 - T/T_c)^{2/9} \quad (A4)$$

Since $T_c \approx 1000$ K for most polymers (1), $-d\gamma/dT$ is therefore practically constant at ordinary temperatures, i.e., $T \ll T_c$.

For polymer pairs that have an upper consolute curve and an UCST (upper critical solution temperature), the interfacial tension decreases with increasing temperature and vanishes at the upper consolute temperature. This is the case for most pairs of immiscible polymers. On the other hand, for polymers that have a lower consolute curve and an LCST (lower critical solution temperature), the interfacial tension vanishes at the lower consolute point and increases with increasing temperature in the immiscible region. A few polymer pairs appear to behave this way (24).

3. Macleod's Relation

The surface tension varies with density ρ according to Macleod's relation (1)

$$\gamma = \gamma^0 \rho^\beta \quad (A5)$$

where γ^0 and β are constants, independent of temperature. β is known as the Macleod's exponent, and usually has a value of 3.0–4.5 for polymers (1). Thus the surface tension is "solely" determined by the density for a given chemical composition.

γ^0 is, to a close approximation, dependent only on the chemical constitution, and is related to Sugden's parachor (1) by

where $\sum P_r$ is the parachor of the repeat unit and M_n is formula weight. Equation (A6) neglects the end group effect (1). The parachor is a group additive quantity, independent of temperature, and its values have been tabulated elsewhere (104,105).

Macleod's relation provides a number of important relationships for analyzing the effects of molecular weight, glass transition, phase transition (crystallization), and chemical constitution on surface tension, as discussed below.

4. Molecular Weight Dependence

The surface tension varies with the number-average molecular weight M_n (1) by

$$\gamma^{1/4} = \gamma_{\infty}^{1/4} - k_1/M_n \quad (A7)$$

where γ_{∞} is the surface tension at infinite molecular weight and k_1 is a constant. Equation (A7) follows directly from Macleod's relation (1). Alternatively, an empirical relation is given (1,81) as

$$\gamma = \gamma_{\infty} - k_2/M_n^{2/3} \quad (A8)$$

where k_2 is a constant. Equations (A7) and (A8) fit the experimental data equally well.

Usually, the surface tension increases with increasing molecular weight. When the molecular weight is greater than about 2000–3000, the surface tension reaches within about 1 mN/m (dyne/cm) of the value at infinite molecular weight. Therefore, the effect of molecular weight may usually be neglected for polymers, except for oligomers. Several exceptions have however been observed and explained in terms of end-group effects (1,4,103).

Relationships similar to Eqs. (A7) and (A8) may be written for the interfacial tension (1,81), i.e.,

$$\gamma^{1/4} = k_0 - k_3/M_{n1} - k_4/M_{n2} \quad (A9)$$

and

$$\gamma_{12} = k'_0 - k'_3/M_{n1}^{2/3} - k'_4/M_{n2}^{2/3} \quad (A10)$$

where $k_0, k_3, k_4, k'_0, k'_3$, and k'_4 are constants, as discussed elsewhere (1).

5. Effects of Glass and Crystal-Melt Transitions

Macleod's relation also provides relationships for the effects of glass and crystal-melt transitions. At the glass transition, the surface tension is continuous, but its temperature coefficient is discontinuous. $(d\gamma/dT)_g$, below the glass temperature, T_g , is related to $(d\gamma/dT)_s$, above T_g (1) by

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where α_g is the isobaric volumetric thermal expansion coefficient in the glassy region and α_r is that in the rubbery region. Since α_g is usually smaller than α_r , the surface tension varies less with temperature in the glassy region than in the rubbery region. Since $-d\gamma/dT$ is usually small, this effect is often neglected when the temperature range of interest is small.

On the other hand, both the surface tension and its temperature coefficient are discontinuous at the crystal-melt transition. The surface tension of crystalline surface, γ_c , is related to that of amorphous surface γ_a (1) by

$$\gamma_c = (\rho_c/\rho_a)^\beta \gamma_a \quad (A12)$$

where ρ_c is the crystalline density, and ρ_a the amorphous density. Since $\beta = 3.0-4.5$, and usually $\rho_c > \rho_a$, the crystalline surface can have a much higher surface tension than the amorphous surface. For example, polyethylene has $\beta = 3.2$, $\rho_c = 0.855 \text{ g/cc}$, $\rho_a = 1.0 \text{ g/cc}$, and $\gamma_a = 35.7 \text{ mN/m}$ at 20°C . Thus its crystalline surface tension is given by

$$\gamma_c = (35.7)(1/0.855)^{3.2} = 58.9 \text{ mN/m} \quad (A8)$$

Note that the value given above refers to a truly crystalline surface. Most "melt-crystallized" semicrystalline polymers, however, have amorphous surface. Only when they are nucleated in the melt against certain nucleating surfaces, or their single crystals are grown from solutions, are crystalline surfaces obtained.

6. Effect of Surface Chemical Constitution

The Macleod-Sugden equation shows that the surface tension depends on surface chemical constitution and density. Since the density is roughly a function of chemical constitution (105), it is expected that a given surface constitution will have a certain "characteristic" surface tension. Some of these values are listed in Table 1. These values should, however, be used only qualitatively.

7. Dispersion (Nonpolar) and Polar Components

The surface tension γ can be separated into dispersion (nonpolar) and polar components (1) i.e.,

$$\gamma = \gamma^d + \gamma^p \quad (A13)$$

where γ^d is the dispersion component (arising from dispersion-force interactions) and γ^p the polar component (arising from various dipolar and specific interactions). The polarity x^p is defined as

$$x^p = \gamma^p/\gamma \quad (A14)$$

which is independent of temperature (1), i.e.,

The interfacial tension is related to the surface tension and the polarity of the two contiguous phases by the harmonic-mean equation (1).

$$\gamma_{12} = \gamma_1 + \gamma_2 - \frac{4\gamma_1^d\gamma_2^d}{\gamma_1^d + \gamma_2^d} = \frac{4\gamma_1^p\gamma_2^p}{\gamma_1^p + \gamma_2^p} \quad (A16)$$

or the geometric-mean equation (1,54,108,109),

$$\gamma_{12} = \gamma_1 + \gamma_2 - 2(\gamma_1^d\gamma_2^d)^{1/2} - 2(\gamma_1^p\gamma_2^p)^{1/2} \quad (A17)$$

where the subscripts 1 and 2 refer to the two individual phases. The harmonic-mean equation has been shown to predict the interfacial tension between polymers adequately, whereas the geometric-mean equation is often less satisfactory (1,4).

The γ^d and γ^p components can be determined either from the interfacial tension or the contact angles by using Eq. (A16), the harmonic-mean equation, or less satisfactorily by Eq. (A17), the geometric-mean equation, as discussed elsewhere (1).

The polarity may also be defined in terms of the cohesive energy density (1), i.e.,

$$x^p = (\Delta E^p/\Delta E) = (\delta^p/\delta)^2 \quad (A18)$$

where ΔE is the cohesive energy density, ΔE^p its polar component, δ the solubility parameter, and δ^p its polar component. The polarity values determined from interfacial properties have been found to agree with those determined from cohesive energy densities for a number of polymers (1). It should be cautioned, however, that Eq. (A14) defines the surface polarity, while Eq. (A18) defines the bulk polarity. These two values may not be the same, if the polymer has sufficiently long surface-active segments which tend to preferentially adsorb on the surfaces.

B. TABLES

Table 1 lists typical values of surface tension for a m surface chemical constitutions.

Table 2 lists the surface tension, its temperature coefficient, polarity, and Macleod's exponent for amorphous surfaces. The surface tension for crystalline surface may be calculated from the amorphous value by using the Macleod's exponent. All data were obtained by direct reversible measurements in the melt. The values for the solid were obtained by extrapolation from the melts. These are the most reliable and preferred. On the other hand, some values were obtained by the contact angle method. These are denoted with the symbol (c). The two values usually agree well.

Table 3 lists the interfacial tension and its temperature coefficient for amorphous interfaces. All data were obtained by direct reversible measurements in the melt. The values for the solid were obtained by extrapolation from the melt. These have been shown to be reliable. The interfacial tension

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may also be estimated from the surface tension and the polarity of the two phases by using the harmonic-mean equation (Eq. (A16)).

TABLE 1. SURFACE CHEMICAL CONSTITUTION AND SURFACE TENSION

Surface chemical constitution	Surface tension at 20°C (mN/m ≡ dyn/cm)
1.1. HYDROCARBON SURFACES	
-CH ₃	30
-CH ₂	36
-CH ₂ - and π CH ₃	43
-CH _n (phenyl ring edge)	43

TABLE 1. *cont'd*

Surface chemical constitution	Surface tension at 20°C (mN/m ≡ dyn/cm)
1.2. FLUOROCARBON SURFACES	
-CF ₃	15
-CF ₂ H	26
-CF ₃ and -CP ₂ -	17
-CF ₂ -	23
-CH ₂ CF ₃	23
-CF ₂ -CFH-	30
-CF ₂ -CH ₂ -	33
-CFH-CH ₂ -	37
1.3. CHLOROCARBON SURFACES	
-CHCl-CH ₂ -	42
-CCl ₂ -CH ₂ -	45
=CCl ₂	50
1.4. SILICONE SURFACES	
-O-Si(CH ₃) ₂ -O-	20
-O-Si(CH ₃)(C ₂ H ₅)-O-	26

TABLE 2. SURFACE TENSION, POLARITY, AND MACLEOD'S EXPONENT FOR AMORPHOUS SURFACES

Polymer	Surface tension γ (mN/m ≡ dyn/cm)				$-\frac{dy}{dT}$ (mN/m/K)	Polarity (ϵ^P)	MacLeod's exponent (β)	Ref.
	20°C	150°C	200°C					
2.1. HYDROCARBON POLYMERS								
Poly(acetylene)								
cis-Isomer	51 (c)	-	-	-	0.08	-	-	5
trans-Isomer	52 (c)	-	-	-	0.05	-	-	5
Poly(butadiene), $M_w \approx 5400$								
carboxyl acid end group	48.6	29.9	22.7	0.1440	-	-	-	70
methyl ester end group	43.1	28.8	23.3	0.1098	-	-	-	70
Poly(butadiene-star-acrylonitrile), carboxyl end group								
18% by weight AN	51.3	40.0	35.7	0.0866	-	-	-	70
$M_w \approx 5300$								
27% by weight AN	52.6	40.2	35.4	0.0955	-	-	-	70
$M_w = 5900$								
Poly(ethylene), branched								
$M_w = 7000$	35.3	26.6	23.3	0.067	0	3.3	1-3,7-14	
$M_w = 2000$	33.7	25.9	22.9	0.060	0	-	13	
Poly(ethylene), linear								
$M_w = \infty$	36.8	29.4	26.6	0.056	0	3.2	9	
$M_w = 67000$	35.7	28.2	25.4	0.057	0	3.2	1-3,7,11 14,15	
Poly(ethylene-star-acrylic acid)								
mol% acrylic acid 20	59 (c)	-	-	-	-	-	-	19
14	55 (c)	-	-	-	-	-	-	19
8	44 (c)	-	-	-	-	-	-	19
3	41 (c)	-	-	-	-	-	-	19
Poly(ethylene-star-propylene)								
mol% PP M_w								
34 37000	33.8	25.7	22.6	0.062	0	3.0	13	
36 33000	33.1	25.4	22.4	0.059	0	3.0	13	
44 15000	32.0	24.1	21.0	0.061	0	3.3	13	
50 63000	31.0	23.5	20.6	0.058	0	3.2	13	
60 58000	30.7	23.2	20.3	0.058	0	2.8	13	
Poly(ethylene-star-propylene-cs-star-hexadiene), EPDM,								
$M_w = 100000$	23.0	0.064	0	-	-	-	-	20

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Surface Tension, Polarity, and Macleod's Exponent for Amorphous Surfaces VI / 525

TABLE 2. cont'd

Polymer	Surface tension γ (mN/m \equiv dyn/cm)			$-\frac{dy}{dT}$ (mN/m/K)	Polarity (x^P)	Macleod's exponent (β)	Refs.
	20°C	150°C	200°C				
Poly(ethylene-stat-vinyl acetate)							
EVA weight ratio 75/25	35.5	26.8	23.5	0.067	0.050	-	12
82.3/17.7	34.1	27.1	24.4	0.054	0.025	-	21-24
73.4/26.6	31.3	26.5	24.7	0.037	0.064	-	21-24
69.1/30.9	30.6	26.4	24.7	0.033	0.083	-	21-24
61.3/38.7	33.0	26.9	24.6	0.047	0.108	-	21-24
Poly(isobutene)							
$M_w = 2700$	33.6	25.3	22.1	0.064	-	4.1	7,11,17,26
Poly(isoprenes)							
cyclo-isomer	32 (c)	-	-	-	-	-	6
cyclized	34 (c)	-	-	-	-	-	6
trans isomer	31 (c)	-	-	-	-	-	6
Poly(4-methyl-1-pentene)	25 (c)	-	-	-	-	-	6
Poly(propylene)							
atactic	29.4	22.1	19.3	0.056	0	3.2	4,11,13,16
isotactic	29.4	22.1	19.3	0.056	0	3.2	4,13
isotactic and atactic mixture	30.1	22.5	19.6	0.058	0.020	3.2	17,18
Poly(styrene) and copolymers, see Styrene Polymers							
Poly(xylylenes), see Styrene Polymers							

12. STYRENE POLYMERS

Poly(2-methylstyrene)							
$M_w = 3000$	38.7	31.1	28.2	0.058	-	4.0	4,17,31
Poly(styrene)							
$M_w = 44000$	40.7	31.4	27.8	0.072	0.168	4.4	8,28-30
$M_w = 9300$	39.4	31.0	27.7	0.065	-	-	31
$M_w = 1700$	39.3	29.2	25.4	0.077	-	-	31
Poly(styrene-stat-acrylonitrile)							
mol% acrylonitrile 32.7	43 (c)	-	-	-	-	-	32
27.6	42 (c)	-	-	-	-	-	32
16.8	40 (c)	-	-	-	-	-	32
6.9	37 (c)	-	-	-	-	-	32
Poly(styrene-stat-2,2,3,3-tetrafluoropropyl) methacrylate							
mol% styrene 98	31 (c)	-	-	-	-	-	33
95	30 (c)	-	-	-	-	-	33
90	29 (c)	-	-	-	-	-	33
80	28 (c)	-	-	-	-	-	33
70	27 (c)	-	-	-	-	-	33
60	26 (c)	-	-	-	-	-	33
50	25 (c)	-	-	-	-	-	33
40	23 (c)	-	-	-	-	-	33
30	21 (c)	-	-	-	-	-	33
20	20 (c)	-	-	-	-	-	33
10	19 (c)	-	-	-	-	-	33
2	19 (c)	-	-	-	-	-	33
1	18 (c)	-	-	-	-	-	33
Poly(xylylene), see also Halogenated Hydrocarbons	46.3 (c)	-	-	-	0.013	-	27

13. HALOGENATED HYDROCARBON POLYMERS

Poly(2-chloro-1,4-xylylene), poly(3-chloro-1,4-phenylene)ethylene)	47.1 (c)	-	-	-	0.019	-	27
Poly(chloroprene)	43.6	32.3	28.0	0.086	0.108	4.2	2,3
$M_w = 30000$							
Poly(chlorotrifluoroethylene)	30.9	22.2	18.9	0.067	0.282	-	1-3,37
Poly(chlorotrifluoroethylene-stat-tetrafluoroethylene)							
Wt% TFE							
60	25.2 (c)	-	-	-	0.348	-	1-3
80	21.3 (c)	-	-	-	0.354	-	1-3
100 (c)	-	-	-	-	0.009	-	27

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TABLE 2. *cont'd*

Polymer	Surface tension γ (mN/m \equiv dyn/cm)			$-\frac{dy}{dT}$ (mN/m/K)	Polarity (x^P)	MacLeod's exponent (β)	Ref.
	20°C	150°C	200°C				
Poly(hexachlorobutadiene)	41.5 (c)	—	—	—	0.019	—	34
Poly(hexafluoropropylene)	17.0 (c)	—	—	—	0.120	—	1-3
Poly(hexafluoropropylene)	12.8 (c)	—	—	—	0.063	—	1-3
Poly(tetrafluoroethylene)							
$M = \infty$	23.0	16.3	13.4	0.058	0.089	—	9
$C_{21}F_{44}$ ($M \approx 1088$)	21.5	13.1	9.8	0.065	—	—	0,38,39
Poly(tetrafluoroethylene-x-ethylene)							
50/50 weight ratio TFE/E	27.6 (c)	—	—	—	0.286	—	1-3
Poly(trifluoromethylene)	27.1 (c)	—	—	—	0.118	—	1-3
Poly(vinyl chloride)	41.9 (c)	—	—	—	0.146	—	1-3
Poly(vinyl fluoride)	38.4 (c)	—	—	—	0.293	—	1-3
Poly(vinylidene chloride)	45.4 (c)	—	—	—	0.196	—	1-3
Poly(vinylidene fluoride)	33.2 (c)	—	—	—	0.376	—	1-3

2.4. VINYL POLYMERS - ESTERS

Poly(ethylene-*styrene*-vinyl acetate), see Hydrocarbon Polymers

Poly(vinyl acetoacetate)	36.5	27.9	24.6	0.066	0.329	3.4	7.12
Poly(vinyl acrylate)	31.1	22.0	18.5	0.070	0.172	3.5	4.40
Poly(vinyl decanoate)	28.9	20.9	17.8	0.062	0.061	3.3	4.40
Poly(vinyl dodecanoate)	29.1	20.9	17.8	0.063	0.044	3.2	4.40
Poly(vinyl hexadecanoate)	30.9	22.5	19.0	0.066	0.035	3.2	4.40
Poly(vinyl hexanoate)	29.4	21.2	18.1	0.063	0.128	3.4	4.40
Poly(vinyl propionate)	14.0	24.7	21.1	0.072	0.221	3.6	4.40
Poly(vinyl octanoate)	28.7	20.7	17.7	0.061	0.078	3.3	4.40

2.5. VINYL POLYMERS - OTHERS

Poly(acrylamide)	52.3 (c)	-	-	-	0.493	-	41
Poly(acrylonitrile)	50 (c)	-	-	-	-	-	41
Poly(heptafluoroisopropoxy)ethylene)	15 (c)	-	-	-	-	-	42
Poly(1-(heptafluoroisopropoxy)methyl propylene- <i>stir</i> -maleic acid)	19 (c)	-	-	-	-	-	43
Poly(1-heptafluoroisopropoxy)propylene)	21 (c)	-	-	-	-	-	42
Poly(methacrylonitrile)	39 (c)	-	-	-	-	-	41
Poly(styrene- <i>stir</i> -acrylonitrile), <i>see</i> Styrene Polymers							
Poly(vinyl acetate)	37 (c)	-	-	-	-	-	44
Poly(vinyl butyral)	38 (c)	-	-	-	-	-	41
Poly(vinyl ethyl ether), poly(ethoxyethylene)	36 (c)	-	-	-	-	-	45
Poly(vinyl methyl ether), poly(methoxyethylcne) $M_n = 46500, M_w = 99000$	31.8	23.1	18.3	0.075	-	-	70
Poly(vinyl formal)	39 (c)	-	-	-	-	-	33

2.6. ACRYLIC POLYMERS - NONFLUORINATED

Poly(acrylamide) see Vinyl Polymers (nones) [\[View\]](#)

Poly(acrylonitrile), see Vinyl Polymers (nonesters)

Poly(*n*-butyl acrylate)

$M_h = 32000$	33.7	24.6	21.1	0.070	0.098	-	1
	30.7	22.8	19.7	0.061	0.127	-	46,107

Poly(ethyl acrylate)
 $M_n = 28000$

Poly(ethylene-*tert*-acrylic acid), see Hydrocarbon

Polymers

Poly(2-ethylhexyl acrylate)

$M_n = 34000$ 30.2 21.1 17.6 0.070 0.028 - 45.107

29.2 21.1 18.0 0.062 0.076 -

Poly(methyl acrylate)

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Surface Tension, Polarity, and Macleod's Exponent for Amorphous Surfaces VI/527

TABLE 2. cont'd

Ref.	Polymer	Surface tension γ (mN/m \equiv dyn/cm)			$-\gamma d\gamma/dT'$ (mN/m/K)	Polarity (χ^P)	Macleod's exponent (β)	Refs.
		20°C	150°C	300°C				
2.7. ACRYLIC POLYMERS - FLUORINATED								
34	Poly(1-chlorodifluoromethyl)tetrafluoroethyl acrylate)	19 (c)	-	-	-	-	-	47
1-3	Poly(di(chlorodifluoromethyl) fluoromethyl acrylate)	20 (c)	-	-	-	-	-	47
1-3	Poly(1,1-dihydroheptafluorobutyl acrylate)	15 (c)	-	-	-	-	-	47
9	Poly(1,1-dihydropentafluoroisopropyl acrylate)	15 (c)	-	-	-	-	-	47
3,39	Poly(1,1-dihydropentadecafluoroctyl acrylate)	10 (c)	-	-	-	-	-	47
1-3	Poly(heptafluoroisopropyl acrylate)	14 (c)	-	-	-	-	-	47
1-3	Poly(5-(heptafluoroisopropoxy)pentyl acrylate)	18 (u)	-	-	-	-	-	47
1-3	Poly(1-(heptafluoroisopropoxy)undecyl acrylate)	20 (c)	-	-	-	-	-	47
1-3	Poly(2-heptafluoropropoxyethyl acrylate)	16 (c)	-	-	-	-	-	47
1-3	Poly(horufluoroisobutyl acrylate)	14 (c)	-	-	-	-	-	47
2.8. METHACRYLIC POLYMERS - NONFLUORINATED								
	Poly(benzyl methacrylate)	36 (c)	-	-	-	-	-	49
	Poly(<i>n</i> -butyl methacrylate) $M_v = 37000$	31.2	23.5	20.6	0.059	0.158	4.2	8
7,12	Poly(isobutyl methacrylate)	30.9	23.1	20.1	0.060	0.139	-	2
1,40	$M_v = 35000$							
1,40	Poly(<i>t</i> -butyl methacrylate)	30.4	22.7	19.8	0.059	0.120	-	2
1,40	Poly(<i>t</i> -butylaminoethyl methacrylate)	34 (c)	-	-	-	-	-	1,35
1,40	Poly(dodecyl methacrylate), poly(lauryl methacrylate)	32.8 (c)	-	-	-	-	-	1,35
1,40	Poly(<i>t</i> -ethyl methacrylate) $M_v = 5200$	35.9	26.8	23.3	0.070	-	-	1,35
	Poly(3-ethylhexyl methacrylate) $M_v = 64000$	28.8	20.8	17.7	0.062	-	-	1,35
41	Poly(<i>n</i> -hexyl methacrylate) $M_v = 52000$	30.0	23.0	18.9	0.062	-	-	1,35
1	Poly(dimethylaminoethyl methacrylate)	36 (c)	-	-	-	-	-	1,35
42	Poly(hydroxyethyl methacrylate), see also Methacrylic Hydrogels	37 (c)	-	-	-	-	-1	5
43	Poly(lauryl methacrylate), see Poly(dodecyl methacrylate)							
	Poly(methyl methacrylate), see also Methacrylic Hydrogels $M = 3000$	41.1	31.2	27.4	0.076	0.281	4.2	8
44	Poly(phenyl methacrylate)	35 (c)	-	-	-	-	-	49
1	Poly(<i>n</i> -propyl methacrylate) $M = 8500$	33.3	24.7	21.5	0.065	-	-	1,35
45	Poly(<i>n</i> -octyl methacrylate), poly(undecadecyl methacrylate)	36.3 (c)	-	-	-	-	-	47
70								
35								
2.9. METHACRYLIC POLYMERS - FLUORINATED								
	Poly(1,1-dihydropentadecafluoroctyl methacrylate)	10.5 (c)	-	-	-	0.048	-	50,53,54
	Poly(heptafluoroisopropyl methacrylate)	15 (c)	-	-	-	-	-	47
	Poly(heptadecafluoroctyl methacrylate)	15.3 (c)	-	-	-	0.094	-	51.52
	Poly(1-hydrotetrafluoroethyl methacrylate)	15 (c)	-	-	-	-	-	47
	Poly(1,1-dihydrotetrafluoropropyl methacrylate)	19 (c)	-	-	-	-	-	33
1	Poly(1-hydrohexafluoroisopropyl methacrylate)	15 (c)	-	-	-	-	-	47.55
107	Poly(<i>t</i> -nonafluorobutyl methacrylate)	15 (c)	-	-	-	-	-	48
	Poly(styrene- <i>star</i> -2,2,3,3-tetrafluoropropyl methacrylate), see Styrene Polymers							
1								
07								
2.10. METHACRYLIC HYDROGELS								
	Polyhydroxyethyl methacrylate) dry	37 (c)	-	-	-	-	-	1,35
	40 wt.% water	69.0 (u)	-	-	-	-	-	56
1	Poly(hydroxyethyl methacrylate- <i>via</i> -dimethyl-							
07	aminooethyl methacrylate) water							

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VI/528 SURFACE AND INTERFACIAL TENSIONS OF POLYMERS, OLIGOMERS, PLASTICIZERS, AND ORGANIC PIGMENTS

TABLE 2. *cont'd*

Polymer	weight ratio	Surface tension γ (mN/m \equiv dyn/cm)			$-d\gamma/dT$ (mN/m/K)	Polarity (α^0)	MacLeod's exponent (β)	Ref.
		20°C	150°C	200°C				
Poly(hydroxyethyl methacrylate-star-methoxyethyl methacrylate)								
weight ratio	wt.% water							
75/25	33	60.1 (c)	-	-	-	0.670	-	56
50/50	23	67.8 (c)	-	-	-	0.608	-	56
25/75	19	68.0 (c)	-	-	-	0.496	-	56
Poly(hydroxyethyl methacrylate-star-methacrylic acid)								
weight ratio	wt.% water							
99.1/0.1	40	68.7 (c)	-	-	-	0.700	-	56
97/3	59	67.6 (c)	-	-	-	0.704	-	56
Poly(hydroxyethyl methacrylate-star-methyl methacrylate)								
weight ratio	wt.% water							
95/5	43	68.6 (c)	-	-	-	0.697	-	56
75/25	43	67.0 (c)	-	-	-	0.640	-	56
50/50	21	65.7 (c)	-	-	-	0.543	-	56
25/75	7	65.6 (c)	-	-	-	0.410	-	56
5/95	3	54.4 (c)	-	-	-	0.393	-	56
Poly(methyl methacrylate), see also Methacrylic Polymers for Dry Surfaces								
3 wt.% water		60.9 (c)	-	-	-	0.282	-	56
Poly(methoxyethyl methacrylate)								
2 wt.% water		71.1 (c)	-	-	-	0.301	-	56

2.11. POLY(ETHERS) (see also POLY(ETHER) COPOLYMERS, POLY(SULFONE), POLY(CARBONATE), PHENOXY RESIN, EPOXY RESIN, VINYL POLYMERS)

Poly(chloral)	37.9 (c)	-	-	-	-	0.037	-	34
Poly(epichlorohydrin)								
$M = 1500$	43.2 (25°C)	-	-	-	-	-	-	57
Poly(oxybutylene)-diol	38.3	28.0	24.0	0.079	0.003	3.7	58	
Poly(oxyisobutylene)-diol								
$M = 30000$	27.5	19.0	13.7	0.066	-	3.8	61	
Poly(oxydecamethylene)	36.1	27.2	23.8	0.068	-	2.8	58	
Poly(oxyethylene)-diol								
$M = 17000$	42.9	30.1	25.2	0.098	0.284	3.0	9,59-61	
Poly(oxyethylene)-diol								
$M = 6000$	43.9	33.0	29.2	0.076	0.284	3.0	9,11,12,	
$M = 6000$	42.5	30.1	25.4	0.095	0.165	2.9	9,62	
Poly(oxyethylene)-dimethylether								
$M = 114$	28.6	16.0	11.1	0.097	-	4.4	9,59-61	
$M = 148$	31.1	18.6	13.8	0.096	-	4.4	9,59-61	
$M = 182$	32.9	20.5	15.8	0.095	-	4.0	9,59-61	
$M = 600$	37.5	26.1	21.7	0.088	-	3.5	9,59-61	
$M = 5000$	44.1	32.7	28.3	0.088	-	3.5	9,56-61	
$M = 100000$	44.2	32.8	28.4	0.088	-	3.2	58	
Poly(oxyhexamethylene)-diol								
43.7 (c)	-	-	-	-	0.316	-	1,35	
Poly(oxymethylen)								
Poly(oxypropylene)-diol								
$M = 302.5$	31.5	21.1	17.1	0.080	-	3.4	62	
$M = ?$	31.7	20.6	16.4	0.085	0.014	3.4	13,57,60,61	
$M = 3000$	31.2	20.9	17.0	0.079	-	3.4	57,60,61	
$M = 400-4100$	31.1	21.6	17.9	0.073	-	3.4		
Poly(oxypropylene)-dimethylether								
$M = 3000$	30.7	18.3	13.6	0.095	-	3.6	57,60,61	
								1,12
								1,13

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TABLE 2. cont'd

Ref.	Polymer	Surface tension γ (mN/m \equiv dyn/cm)			- $d\gamma/dT$ (mN/m/K)	Polarity (x^p)	Macleod's exponent (β)	Refs.					
		20°C	150°C	200°C									
2.12. POLY(ETHER) COPOLYMERS													
Poly(oxyethylene)-block-poly(oxypropylene)-block-poly(oxyethylene)													
56	wt.% OP	DP of blocks											
		OE	OP	OE									
56	10.0	46	16	46	36.8	27.8	24.3	0.069	0.129	2.8	57,60,62		
56	18.0	11	16	11	34.2	25.0	21.5	0.071	0.105	3.0	57,60,62		
56	56.0	8	16	8	33.7	24.3	20.7	0.072	0.094	3.1	57,60,62		
56	84.1	2	16	2	32.9	22.8	18.9	0.078	0.047	3.4	57,60,62		
56	19.0	75	30	75	34.7	26.6	23.5	0.062	0.096	2.5	57,60,62		
56	55.1	13	30	13	33.4	24.7	21.3	0.067	-	2.7	57,60,62		
56	59.6	10	30	10	32.7	23.7	20.2	0.069	-	2.8	57,60,62		
56	85.3	3	30	3	31.8	22.1	18.4	0.074	-	3.3	57,60,62		
56	18.9	110	39	110	33.8	26.3	23.4	0.058	0.095	2.6	57,60,62		
56	20.2	122	47	122	33.3	26.0	23.2	0.056	0.074	2.4	57,60,62		
56	20.2	139	56	139	32.3	25.5	22.9	0.052	0.069	2.5	57,60,62		
56	38.3	56	56	56	32.4	25.0	22.1	0.057	-	2.6	57,60,62		
56	57.7	28	56	28	32.1	24.4	21.4	0.059	-	2.7	57,60,62		
56	66.7	19	56	19	31.9	23.8	20.7	0.062	-	2.8	57,60,62		
56	86.7	6	56	6	31.7	23.2	20.0	0.065	-	2.9	57,60,62		
Poly(oxyethylene-star-oxypropylene)													
mol% oxypropylene													
ESIN.	17				40.5	28.1	23.4	0.095	0.139	3.6	57,62		
	30				39.3	26.9	22.2	0.095	0.127	3.6	57,62		
	41				37.5	25.5	20.9	0.092	0.112	3.6	57,62		
	56				34.9	23.2	18.7	0.090	0.061	3.6	57,62		
	76				33.4	22.3	18.0	0.086	0.040	3.3	57,62		
	85				32.4	21.3	17.0	0.086	0.031	3.4	57,62		
34	Poly(oxyethylene-star-oxypropylene)-block-poly(oxydimethylsilylene)-block-poly(oxyethylene-star-oxypropylene): i.e., Poly(oxyethylene-star-oxypropylene) has a comonomer weight ratio of 50/50, $M_n = 2200$												
57	wt.% of polysiloxane	DP of polysiloxane											
58	0	0			34.8 (25°C)	-	-	-	-	-	63		
61	4.6	4.9			28.0 (25°C)	-	-	-	-	-	63		
58	7.5	7.9			25.4 (25°C)	-	-	-	-	-	63		
9-61	9.9	10.4			21.4 (25°C)	-	-	-	-	-	63		
9-61	19.8	20.8			20.6 (25°C)	-	-	-	-	-	63		
1.13.	32.6	34.3			20.5 (25°C)	-	-	-	-	-	63		
9.62	Poly(oxytetramethylene-star-oxypropylene)												
1-61	mol%	M_w											
1-61	Oxypropylene												
1-61	25	2100			36.4	26.0	22.0	0.080	-	3.3	13		
1-61	35	1200			36.0	25.7	21.8	0.079	-	3.2	13		
1-61	46	1900			34.9	24.3	20.2	0.082	-	3.5	13		
58	52	2250			34.3	23.8	19.7	0.081	-	3.5	13		
1.35	67	2200			33.1	23.8	18.9	0.079	-	3.4	13		
13	85	1700			31.9	21.6	17.7	0.070	-	3.5	13		
62	2.13. POLY(ESTERS)												
61	Poly(oxydecamethyleneoxyisophthaloyl), Poly(decamethylene Isophthalate)				42.7	33.3	29.7	0.072	0.192	3.0	91		

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VI / 530 SURFACE AND INTERFACIAL TENSIONS OF POLYMERS, OLIGOMERS, PLASTICIZERS, AND ORGANIC PIGMENTS

TABLE 2. *cont'd*

Polymer	Surface tension γ (mN/m \equiv dyn/cm)			$-dy/dT$ (mN/m/K)	Polarity (x^P)	MacLeod's exponent (β)	Ref.
	20°C	150°C	200°C				
→ Poly(oxyethyleneoxyterephthaloyl), poly(ethylene terephthalate) $M_n = 16000 M_w = 37000$	44.6	36.2 27.7 (280°C)	32.9 24.8 (325°C)	0.065	0.221 \rightarrow	—	1,14,20,64
→ Poly(oxyhexamethyleneoxyisophthaloyl), poly hexamethylene isophthalate	43.6	35.6	31.7	0.077	0.242 \rightarrow	3.3	98
→ Poly(oxytricethyleneoxyisophthaloyl), poly(butylene isophthalate)	47.8	37.4	33.4	0.080	0.270 \rightarrow	3.2	98
→ Poly(oxytrimethyleneoxyisophthaloyl), poly(propylene isophthalate)	49.3	38.5	34.3	0.083	0.288 \rightarrow	3.0	98
2.14. POLY(CARBONATES)							
Poly(oxycarbonyloxy-1, 4-phenyleneisopropylidene- 1,4-phenylene), polycarbonate of bisphenol-A	42.9	35.1	32.1	0.060	0.246	—	35
	45 (c)	—	—	—	—	—	65
2.15. POLY(SULFONES)							
Poly(oxy-1,4-phenyleneoxy-1,4-phenyleneoxy- 1,4-phenyleneisopropylidene-1,4-phenylene), polysulfone	46.6 (c)	—	—	—	0.347	—	35
2.16. PHENOXY RESINS							
Poly(oxy-1,4-phenyleneisopropylidene- 1,4-phenyleneoxy-2-hydroxytrimethylene), phenoxy resin $M = 30000$	43.0	—	—	—	—	—	35
2.17. EPOXY RESINS							
Diglycidyl ether of bisphenol-A, 2,3-di(glycidoxy- 1,4-phenylene) propane pure, $M = 340$	47.2	—	—	—	—	—	67
	45.6	—	—	—	0.432	—	35,68
Diglycidyl ether of bisphenol-A, 2,3-(diglycidoxy- 1,4-phenylene)propane chain extended with bisphenol-A	51.2 (23 °C)	—	—	—	—	—	85
Diglycidyl ether of bisphenol-A with 6 wt.% of <i>N,N</i> -diethylaminopropylamine fresh, mixture, not cured	33.7	—	—	—	—	—	67,68
	46.8 (c)	—	—	—	—	—	35
Diglycidyl ether of bisphenol-A with stoichiometric amount of triethylenetetramine cured	39.1 (c)	—	—	—	0.166	—	35
Diglycidyl ether of bisphenol-A with 0.5 wt.% of <i>N</i> -methylaminopropyltrimethoxysilane fresh, mixture, not cured	39.1	—	—	—	—	—	68
Diglycidyl ether of bisphenol-A with 0.5 wt.% of γ -glycidoxypropyltrimethoxysilane fresh, mixture, not cured	32.9	—	—	—	—	—	68
Curing agent: γ -aminopropyltrimethoxysilane $M = 179$	25.5	—	—	—	—	—	68
Curing agent: <i>N,N</i> -diethylaminopropylamine $M = 186$	25.3	—	—	—	—	—	68
Curing agent: <i>N,N</i> -diethylaminopropylamine $M = 130$	24.6	—	—	—	—	—	68
Curing agent: <i>N,N</i> -dimethylaminopropylamine $M = 102$	23.9	—	—	—	—	—	68
Curing agent: <i>N</i> -methylaminopropyltrimethoxysilane $M = 193$	27.0	—	—	—	—	—	68
Curing agent: γ -glycidoxypropyltrimethoxysilane $M = 236$	23.9	—	—	—	—	—	68
2.18. POLY(AMIDES)							

Surface Tension, Polarity, and MacLeod's Exponent for Amorphous Surfaces VI / 531

TABLE 2. cont'd

Polymer	Surface tension γ (mN/m \equiv dyn/cm)			- $d\gamma/dT$ (mN/m/K)	Polarity (χ^P)	MacLeod's exponent (β)	Refs.
	20°C	150°C	200°C				
Poly(imino(1-oxododecamethylene)) (nylon 12)	35.8 (c)	-	-	-	0.154	-	73
Poly(imino(1-oxohexamethylene)) (nylon 6)	38.4 (c)	-	-	-	0.188	-	35
Poly(imino(1-oxotetramethylene)) (nylon 4)	48.5 (c)	-	-	36.1 (265°C)	-	-	72, 73
Poly(imino-1,4-phenyleneiminoterephthaloyl), poly(1,4-phenylene terephthalamide) fiber (unsized)	48.5 (c)	-	-	-	0.216	-	74
cast sheet (H-bonding parallel to surface)	33.7 (c)	-	-	-	0.206	-	75
cast sheet (H-bonding vertical to surface)	31.3 (c)	-	-	-	0.202	-	75
Poly(imino adipoyliminohexamethylene) (nylon 66) $M_w = 17000, M_n = 35000$	46.5	38.1	34.8	0.065	0.344	-	1, 14, 20
Poly(iminoazelaoyliminononamethylene) (nylon 99)	36 (c)	-	-	-	-	-	71
Poly(iminopimeloyliminohexamethylene) (nylon 77)	43 (c)	-	-	-	-	-	71
Poly(iminosebacoyliminododecamethylene) (nylon 1010)	32 (c)	-	-	-	-	-	71
Poly(iminosebacoyleiminohexamethylene) (nylon 610)	-	-	37.0 (265°C)	-	-	-	72
Poly(iminosebacyliminoctamethylene) (nylon 88)	34 (c)	-	-	-	-	-	71
2.19. POLY(IMIDES)							
Poly(iminocarbonyl-(4,6-dicarboxy-1,3-phenylene)-carbonylimino-1,4-phenyleneoxy-1,4-phenylene), KAPTON H film		41.0 (c)	-	-	-	0.358	-
	37.7 (c)	-	-	-	-	0.223	-
2.20. POLY(IMINES)							
Poly((benzoylimino)ethylene)	26 (c)	-	-	-	-	-	77
Poly((butyrylimino)ethylene)	25 (c)	-	-	-	-	-	77
Poly((dodecanoylimino)ethylene)	22 (c)	-	-	-	-	-	78
Poly((dodecanoylimino)ethylene- <i>stir</i> -(acetyl)imino trimethylene)	22 (c)	-	-	-	-	-	78
Poly((heptanoylimino)ethylene)	22 (c)	-	-	-	-	-	77
Poly((hexanoylimino)ethylene)	23 (c)	-	-	-	-	-	77
Poly((3-methyl)butyrylimino)ethylene)	24 (c)	-	-	-	-	-	77
Poly((pentadecafluoroctadecanoylimino)ethylene)	11 (c)	-	-	-	-	-	77
Poly((pentanoylimino)ethylene)	23 (c)	-	-	-	-	-	77
2.21. POLY(URETHANES)							
Poly(methylenediphenyldiisocyanate- <i>alt</i> -(butanediol poly(oxytetramethylene)diol) (ESTANE 5714)	39 (c)	-	-	-	-	0.179	-
Poly(hexamethylene diisocyanate- <i>alt</i> -triethylene glycol)	38.6 (c)	-	-	-	-	0.194	-
Poly(4-methyl-1,3-phenylene diisocyanate- <i>alt</i> -tripropylene glycol)	36.3 (c)	-	-	-	-	0.344	-
2.22. POLY(SILOXANES) (see also ORGANOSILANES)							
Poly(oxydiethylsilylene) 158 cS	25.7	16.2	12.5	0.073	-	-	8
Polyoxydimethylsilylene $M_w = 75000$	20.39 21.17	14.15	11.75	0.048	0.042	← 3.5	2 2 8

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TABLE 2. *contd*

Polymer	Surface tension γ (mN/m \equiv dyn/cm)			$-\frac{dy}{dT}$ (mN/m/K)	Polarity (χ^P)	MacLeod's exponent (β)	Ref.
	20°C	150°C	200°C				
$M = 3900$	20.17	13.93	11.53	0.048	0.042	3.5	2,9
	20.59	—	—	—	—	—	26
	20.47	12.93	10.03	0.058	—	—	83
	19.8	13.5	11.1	0.048	0.042	3.5	2,11,14, 80,82
60000 cS	—	—	—	—	—	3.5	80-82
$M = 1274$	19.9	—	—	—	—	3.7	80-82
$M = 607$	18.8	—	—	—	—	3.7	80-82
$M = 310$	17.6	—	—	—	—	4.0	80-82
$M = 162$	15.7	—	—	—	—	—	—
Poly(oxydimethylsilylene), α,ω -difunctional [R-(Si(CH ₃) ₂ -O-) _n -Si(CH ₃) ₂ -R] R = (CH ₂) ₃ NH ₂	20.88	14.12	11.52	0.052	—	—	70
$M_n = 2086$	19.86	12.97	10.32	0.053	—	—	70
$M_n = 7916$	—	—	—	—	—	—	—
Poly(oxydimethylsilylene), α,ω -difunctional R-(Si(CH ₃) ₂ -O-) _n -Si(CH ₃) ₂ -R R = (CH ₂) ₃ NH ₂ ; $M_n = 1132$	21.00	14.37	11.82	0.051	—	—	70
R = (CH ₂) ₃ COOH; $M_n = 2194$	20.54	13.52	10.82	0.054	—	—	70
Poly(oxydimethylsilylene) block copolymers, see Poly(ester) Copolymers	—	—	—	—	—	—	—
Poly(oxydimethylphenylsilylene) 102 cS	26.1	11.8	6.3	0.11	—	—	80

2.23. ORGANOSILANES - HYDROLYZED AND CONDENSED FILMS (see also POLYSILOXANES and EPOXY RESINS)

2.23.1. ALKYL AND ALKYLENE SILANES

Ethyltriethoxysilane, CH ₃ CH ₂ Si(OCH ₃) ₃	36.7 (c)	—	—	—	—	—	1,35
on silica (no catalyst)	34.5 (c)	—	—	—	—	—	1,35
on silica (acetic acid catalyst)	27.8 (c)	—	—	—	—	—	1,35
on silica (propionic acid catalyst)	33.4 (c)	—	—	—	—	—	1,35
on silica (piperidine catalyst)	—	—	—	—	—	—	—
γ -Methacryloxypropyltrimethoxysilane, CH ₂ =C(CH ₃)-C(=O)O(CH ₂) ₂ Si(OCH ₃) ₃	44.8 (c)	—	—	—	—	—	1,35
on soda-lime glass	28.0 (c)	—	—	—	—	—	1,35
Methyltrimethoxysilane, CH ₃ Si(OCH ₃) ₃	43.0 (c)	—	—	—	—	—	1,35
on soda-lime glass	33.4 (c)	—	—	—	—	—	1,35
Vinyltrimethoxysilane, CH ₂ =CHSi(OCH ₃) ₃	33.4 (c)	—	—	—	—	—	1,35
on silica	28.6 (c)	—	—	—	—	—	1,35
Vinyltrimethoxysilane, CH ₂ =CHSi(OCH ₃) ₃	35.7 (c)	—	—	—	—	—	1,35
on soda-lime glass	—	—	—	—	—	—	—

2.23.2. AMINO SILANES

N- β -(aminoethyl)- γ -aminopropyltrimethoxysilane, NH ₂ (CH ₂) ₂ NH(CH ₂) ₃ Si(OCH ₃) ₃	33.7 (c)	—	—	—	—	—	1,35
on soda-lime glass	—	—	—	—	—	—	—
γ -Aminopropyltrimethoxysilane, NH ₂ CH ₂ CH ₂ CH ₂ Si(OCH ₃) ₃	35.7 (c)	—	—	—	—	—	1,35
on soda-lime glass	—	—	—	—	—	—	—

2.23.3. EPOXY SILANE

Oligo(dioxypropyl)trimethoxysilane, H ₂ C=C(CH ₂ O(CH ₂) ₂ Si(OCH ₃) ₃	49.4 (c)	—	—	—	—	—	1,35
on soda-lime glass (no catalyst)	66.9 (c)	—	—	—	—	—	1,35

2.23.4. HALOGENATED ALKYL SILANES

α -Bromophenyltrimethoxysilane, BrC ₆ H ₄ Si(OCH ₃) ₃	—	—	—	—	—	—	1,35
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P. 22

Surface Tension, Polarity, and Macleod's Exponent for Amorphous Surfaces

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TABLE 2. *cont'd*

Ref.	Polymer	Surface tension γ (mN/m \equiv dyn/cm)			-d γ /dT (mN/m/K)	Polarity (x ^P)	Macleod's exponent (β)	Refs.
		20°C	150°C	200°C				
2,9	on silica	49.9 (c)	—	—	—	—	—	1,35
26	on stainless steel	53.3 (c)	—	—	—	—	—	1,35
83	on α -alumina	49.9 (c)	—	—	—	—	—	1,35
1,14, 80,82	γ -Chloropropyltrimethoxysilane, $\text{Cl}(\text{CH}_2)_3\text{Si}(\text{OCH}_3)_3$	40.7 (c)	—	—	—	—	—	1,35
10-82	on soda-lime glass	48.8 (c)	—	—	—	—	—	1,35
80-82	on pyrex glass	49.9 (c)	—	—	—	—	—	1,35
80-82	on stainless steel	—	—	—	—	—	—	1,35
1-14, 80,82	1-(1,1-Dihydroperfluoroctoxy)propyltrimethoxysilane, $\text{CF}_3(\text{CF}_2)_6\text{CH}_2\text{O}(\text{CH}_2)_3\text{Si}(\text{OC}_2\text{H}_5)_3$	21.5 (c)	—	—	—	—	—	1,35
70	on gold	18.8 (c)	—	—	—	—	—	1,35
70	on pyrex glass	18.8 (c)	—	—	—	—	—	1,35
70	on stainless steel	—	—	—	—	—	—	1,35
70	γ -Perfluoroisopropoxypropyltrimethoxysilane, $(\text{CF}_3)_2\text{CFO}(\text{CH}_2)_3\text{Si}(\text{OCH}_3)_3$	24.2 (c)	—	—	—	—	—	1,35
70	on pyrex glass	22.8 (c)	—	—	—	—	—	1,35
70	on silica	18.8 (c)	—	—	—	—	—	1,35
70	on stainless steel	—	—	—	—	—	—	1,35
2,3,5. MERCAPTO SILANS								
81	γ -Mercaptopropyltrimethoxysilane, $\text{HS}(\text{CH}_2)_3\text{Si}(\text{OCH}_3)_3$	41.9 (c)	—	—	—	—	—	1,35
on soda-lime glass								
2,24. CELLULOSEICS								
1,35	Amylose	37 (c)	—	—	—	—	—	84
1,35	Amylopectin	35 (c)	—	—	—	—	—	84
1,35	Cellophane	45.4 (c)	—	—	—	0.344	—	51,52
1,35	Cellulose	—	—	—	—	—	—	86
1,35	regenerated from cotton	42 (c)	—	—	—	—	—	86
1,35	regenerated from wood pulp	36-42 (c)	—	—	—	—	—	51,52,87,88
1,35	Cellulose acetate	45.9 (c)	—	—	—	—	—	—
1,35	Cellulose acetate butyrate	34 (c)	—	—	—	—	—	—
1,35	Ethyl cellulose	32 (c)	—	—	—	—	—	—
1,35	Hemicellulose	—	—	—	—	—	—	86
1,35	arabinogalactan	33 (c)	—	—	—	—	—	86
1,35	galactoglucomannan	37 (c)	—	—	—	—	—	86
1,35	hardwood xylan	33-37 (c)	—	—	—	—	—	86
1,35	softwood xylan	35 (c)	—	—	—	—	—	86
1,35	Nitrocellulose	38 (c)	—	—	—	—	—	86
1,35	Starch	39 (c)	—	—	—	—	—	86
1,35	2,25. POLY(PEPTIDES)							9
1,35	Casein	43 (c)	—	—	—	—	—	52,9
1,35	Poly(L-alanine)	48.2 (c)	—	—	—	0.203	—	52,9
1,35	Poly(γ -benzyl L-glutamate)	39.2 (c)	—	—	—	0.224	—	52,9
1,35	Poly(glycine), (oxylon2)	50.1 (c)	—	—	—	0.443	—	52,9
1,35	Poly(γ -methyl L-glutamate)	—	—	—	—	—	—	52,9
1,35	α -helix random tangle	44.0 (c)	—	—	—	0.375	—	52,9
1,35	α -sheet	48.0 (c)	—	—	—	0.192	—	52,9
1,35	α -helix on water	44.4 (c)	—	—	—	0.435	—	52,9
1,35	β -extended chain	35.5 (c)	—	—	—	0.191	—	52,9
1,35	β -sheet	37.8 (c)	—	—	—	0.119	—	52,9
1,35	β -random chain	45.4 (c)	—	—	—	0.440	—	52,9
1,35	Mixed α and β sheet	42.1 (c)	—	—	—	0.359	—	52,9
1,35	Wool	45 (c)	—	—	—	—	—	—
1,35	2,26. MISCELLANEOUS							
1,35	2,26.1. HYDROCARBONS							
1,35	Eicosane, $\text{C}_{20}\text{H}_{42}$	28.9	25.6 (60°C)	—	0.0833	0	—	1,9,62,1
1,35	$M = 200$	—	—	—	0.066	0	—	1,9,94,1

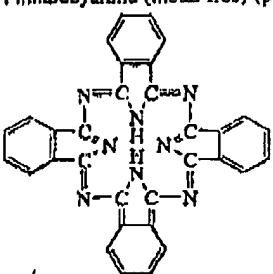
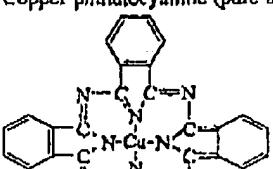
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FAX NO.

P. 23

VI/534 SURFACE AND INTERFACIAL TENSIONS OF POLYMERS, OLIGOMERS, PLASTICIZERS, AND ORGANIC PIGMENTS

TABLE 2. cont'd

Polymer	Surface tension γ (mN/m \equiv dyn/cm)				- $d\gamma/dT$ (mN/m/K)	Polarity (χ^P)	MacLeod's exponent (β)	Ref.
	20°C	150°C	200°C					
Paraffin wax (mp 65°C)	34.7	32.0 (65°C)	26.9 (150°C) 0.06		0	-	-	1,94,95
31.0 (c)	-	-			-	-	-	1
25.5 (c)	-	-	-	-	-	-	-	108
2.26.2. ALKANE-DIOLS								
1,4-Butanediol, $M = 90$	44.2	37.6 (90°C)	-	0.094	0.330	3.6	-	58
1,10-Decanediol, $M = 174$	39.3	34.2 (90°C)	-	0.073	0.137	2.9	-	58
1,6-Hexanediol, $M \approx 118$	42.2	36.5 (90°C)	-	0.081	0.238	3.3	-	58
1,5-Pentanediol, $M = 104$	41.6	36.7 (90°C)	-	0.070	0.281	2.8	-	58
1,3-Propanediol, $M = 76$	45.9	38.9 (90°C)	-	0.100	0.375	3.6	-	58
2.26.3. ADHESIVES								
Natural rubber + ester resin pressure sensitive adhesive	36 (c)	-	-	-	-	-	-	45,101
Poly(isobutylene)-based pressure sensitive adhesive	30 (c)	-	-	-	-	-	-	101
Phenol-resorcinol adhesive	52 (c)	-	-	-	-	-	-	93
Resorcinol adhesive	51 (c)	-	-	-	-	-	-	90
Urea-formaldehyde adhesive	61 (c)	-	-	-	-	-	-	90
2.26.4. SULFUR								
"Monomeric" sulfur, below the floor temperature of 160°C								
$\gamma = 72.95 - 0.10197T$, for $T = 120 - 160°C$								97
"Polymeric" sulfur, above the floor temperature of 160°C								97
$\gamma = 65.31 - 0.0553T$, for $T = 160 - 440°C$								97
Solid sulfur	128 (c)	-	-	-	-	-	-	96
2.26.5. PLASTICIZERS								
Di(<i>n</i> -butyl)- <i>o</i> -phthalate $M = 278$	33.1	23.1	19.2	0.077	0.061	3.4	-	100
Di(<i>n</i> -dodecyl)- <i>o</i> -phthalate $M = 502$	30.8	22.6	19.5	0.063	0.029	2.9	-	100
Di(<i>ethyl</i>)- <i>o</i> -phthalate $M = 232$	36.6	24.6	20.0	0.092	0.115	3.8	-	100
Di(<i>n</i> -heptyl)- <i>o</i> -phthalate $M = 362$	30.0	20.6	17.0	0.072	0.047	3.5	-	100
Di(methyl)- <i>o</i> -phthalate $M = 194$	39.5	26.9	22.0	0.097	0.190	3.7	-	100
Di(<i>n</i> -nonyl)- <i>o</i> -phthalate $M = 418$	28.9	19.9	16.5	0.069	0.028	3.4	-	100
Di(<i>n</i> -propyl)- <i>o</i> -phthalate $M = 250$	34.4	23.3	19.1	0.085	0.067	3.3	-	100
Tricresyl phosphate	40.9	-	-	-	0.027	-	-	1
2.26.6. ORGANIC PIGMENTS								
Phthalocyanine (metal-free) (pure untreated surface)								
	52.8 (c)	-	-	-	0.240	-	-	1,99
Copper phthalocyanine (pure untreated surface)								
	46.9 (c)	-	-	-	0.147	-	-	1,99

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P. 24

Interfacial Tension for Amorphous Interfaces VI / 535

TABLE 2. cont'd

Polymer	Surface tension γ (mN/m \equiv dyn/cm)			$-\frac{d\gamma}{dT}$ (mN/m/K)	Polarity (χ^P)	MacLeod's exponent (β)	Ref.
	20°C	150°C	200°C				
Chlorinated copper phthalocyanine (pure untreated surface)	43.0 (c)	-	-	-	0.148	-	1,99
Indanthrone (pure untreated surface)							
	63.2 (c)	-	-	-	0.475	-	1,99
Isindolinone (pure untreated surface)							
	47.2 (c)	-	-	-	0.318	-	1,99
Manganese β -oxynaphthalic acid derivative (pure untreated surface)							
	51.9 (c)	-	-	-	0.464	-	1,99
γ -Quinacridone (pure untreated surface)							
	49.1 (c)	-	-	-	0.273	-	1,99
Thioindigo red (pure untreated surface)							
	51.4 (c)	-	-	-	0.317	-	1,99
Toluidine red (pure untreated surface)							
	53.0 (c)	-	-	-	0.251	-	1,99

TABLE 3. INTERFACIAL TENSION FOR AMORPHOUS INTERFACES

Polymer	Interfacial tension γ_{12} (mN/m \equiv dyn/cm)			$-\frac{d\gamma_{12}}{dT}$ (mN/m/K)	Ref.
	20°C	150°C	200°C		
1,99					
1.I. HYDROCARBON POLYMERS vs. OTHERS					
1.I.I. POLY(BUTADIENE) vs. OTHERS	2.48	2.07	1.91	0.00322	11

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FAX NO.

P. 25

VI/536 SURFACE AND INTERFACIAL TENSIONS OF POLYMERS, OLIGOMERS, PLASTICIZERS, AND ORGANIC PIGMENTS

TABLE 3. *cont'd*

Polymer	Interfacial tension γ_{12} (mN/m \equiv dyn/cm)			$-\frac{d\gamma_{12}}{dT}$ (mN/m/K)	Ref.
	20°C	150°C	200°C		
Poly(butadiene) vs. poly(oxydimethylsilylene) PBD $M_n = 2350$, PDMS $M_n = 3900$	3.86	2.70	2.25	0.00895	103
Poly(butadiene) vs. poly(oxydimethylsilylene) PBD $M_n = 2350$, PDMS $M_n = 5200$	3.98	2.85	2.42	0.00865	103
Poly(butadiene) vs. poly(oxydierhylsilylene) PBD $M_n = 960$, PDMS $M_n = 5200$	2.58	2.35	2.13	0.00250	103
Poly(butadiene) vs. epoxy resin (diglycidyl ether of bisphenol-A, chain extended with bisphenol-A)	1.77 (23°C)	1.40 (55°C)	-	0.0105	70
3.1.2. POLY(BUTADIENE-<i>stat</i>-ACRYLONITRILE) vs. OTHERS					
Poly(butadiene- <i>stat</i> -acrylonitrile) 18 wt.% AN vs. epoxy resin (same as above)	1.23	0.57 (55°C)	-	0.0198	70
Poly(butadiene- <i>stat</i> -acrylonitrile) 26 wt.% AN vs. epoxy resin (same as above)	-	0.58 (55°C)	-	-	70
3.1.3. POLY(ETHYLENE) vs. OTHERS					
Poly(ethylene) (branched) vs. poly(propylene) (atactic)	-	1.1	-	-	17
Poly(ethylene) (linear) vs. poly(styrene)	8.3	5.7	4.7	0.020	8
-	-	4.4	-	-	106
Poly(ethylene) (branched) vs. poly(styrene)	5.6	5.0	4.8	0.0046	46
Poly(ethylene) (branched) vs. poly(chloroprene)	4.6	3.0	3.2	0.0075	2
Poly(ethylene) (linear) vs. poly(methyl acrylate)	10.6	8.2	7.3	0.018	135
Poly(ethylene) (branched) vs. poly(methyl acrylate)	-	6.5	-	-	46
Poly(ethylene) (linear) vs. poly(ethyl acrylate)	7.5	5.4	4.6	0.016	135
Poly(ethylene) (branched) vs. poly(ethyl acrylate)	-	5.5	-	-	46
Poly(ethylene) (linear) vs. poly(<i>n</i> -butyl acrylate)	5.0	3.3	2.7	0.014	135
Poly(ethylene) (branched) vs. poly(<i>n</i> -butyl acrylate)	5.5	3.8	3.2	0.013	46,107
Poly(ethylene) (linear) vs. poly(2-ethylhexyl acrylate)	3.1	1.8	1.3	0.010	135
Poly(ethylene) (branched) vs. poly(2-ethylhexyl acrylate)	3.5	2.5	2.1	0.0078	46,107
Poly(ethylene) (linear) vs. poly(methyl methacrylate)	11.8	9.5	8.6	0.018	8
Poly(ethylene) (linear) vs. poly(<i>n</i> -butyl methacrylate)	7.1	5.1	4.4	0.015	8
Poly(ethylene) (branched) vs. poly(<i>iso</i> -butyl methacrylate)	5.5	4.2	3.7	0.010	2
Poly(ethylene) (branched) vs. poly(<i>tert</i> -butyl methacrylate)	5.9	4.7	4.3	0.009	2
Poly(ethylene) (linear) vs. poly(poly(vinyl acetate))	14.6	11.0	9.7	0.027	7,12
Poly(ethylene) (branched) vs. poly(vinyl acetate)	-	10.5	-	-	18
Poly(ethylene) (branched) vs. poly(ethylene- <i>stat</i> -vinyl acetate), 25 wt.% VAc	2.0	1.3	1.1	0.005	12,18
Poly(ethylene) vs. poly(ethylene- <i>stat</i> -vinyl acetate), 12 wt.% VAc	-	0.3	-	-	23
Poly(ethylene) vs. poly(ethylene- <i>stat</i> -vinyl acetate), 17.7 wt.% VAc	-	0.8	-	-	23
Poly(ethylene) vs. poly(ethylene- <i>stat</i> -vinyl acetate), 25 wt.% VAc	-	1.5	-	-	23
Poly(ethylene) vs. poly(ethylene- <i>stat</i> -vinyl acetate), 26.6 wt.% VAc	-	1.7	-	-	23
Poly(ethylene) vs. poly(ethylene- <i>stat</i> -vinyl acetate), 30.9 wt.% VAc	-	2.2	-	-	23
Poly(ethylene) vs. poly(ethylene- <i>stat</i> -vinyl acetate), 38.7 wt.% VAc	-	2.9	-	-	35
Poly(ethylene) vs. poly(ethylene- <i>stat</i> -vinyl acetate), 50 wt.% VAc	-	4.1	-	-	35
Poly(ethylene) vs. poly(ethylene- <i>stat</i> -vinyl acetate), 75 wt.% VAc	-	7.3	-	-	35
Poly(ethylene) (linear) vs. poly(oxyethyleneoxyterephthaloyl)	9.4	6.5 (280°C)	6.0 (325°C)	-	14
Poly(ethylene) (branched) vs. poly(oxyethyleneoxyterephthaloyl)	13.7	9.8 (280°C)	9.2 (325°C)	-	98
Poly(ethylene) (branched) vs. poly(oxytrimethyleneoxy-isophthaloyl)	15.4	11.5	10.0	0.030	98
Poly(ethylene) (branched) vs. poly(oxytrimethyleneoxy-isophthaloyl)	13.5	10.1	8.8	0.026	98
Poly(ethylene) (branched) vs. poly(oxyhexamethyleneoxy-isophthaloyl)	11.1	8.4	7.3	0.021	98
Poly(ethylene) (branched) vs. poly(oxyisophthaloyloxydodecamethylene)	8.3	6.4	5.6	0.015	98
Poly(ethylene) (branched) vs. poly(oxyisophthaloyloxydodecamethylene)	5.9	4.5	3.9	0.011	98
Poly(ethylene) (linear) vs. poly(iminohexamethylene-iminodipropyl) (nylon 66)	14.9	10.2 (280°C)	9.4 (325°C)	-	35
Poly(ethylene) (branched) vs. poly(iminohexamethylene-iminodipropyl) (nylon 66)	-	17.0 (280°C)	15.2 (325°C)	0.041	14
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P. 26

Interfacial Tension for Amorphous Interfaces

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TABLE 3. cont'd

Polymer	Interfacial tension γ_{12} (mN/m \equiv dy/cm)			$\sim \frac{dy_{12}}{dT}$ (mN/m/K)	Refs.
	20°C	150°C	200°C		
Poly(ethylene) (branched) vs. poly(oxytetramethylene)	5.1	4.1	3.8	0.007	2,12
Poly(ethylene) (branched) vs. poly(oxydimethylsilylene)	5.3	5.1	5.0	0.002	2,12,82
3.1.4. POLY(ETHYLENE- <i>stat</i> -PROPYLENE- <i>stat</i> -HEXADIENE), (EPDM) vs. OTHERS					
EPDM (E/P/HD 69.5/26.5/4.0 weight ratio) vs. poly-(oxyethyleneoxyterephthaloyl), poly(ethylene terephthalate)	8.6	6.2 (280°C)	5.7 (325°C)	0.0093	20,35
EPDM (E/P/HD 69.5/6.5/4.0 weight ratio) vs. poly(imino-hexamethylenedecimino adipoyl) (nylon 66)	14.7	9.7 (280°C)	8.8 (325°C)	0.0193	20,35
Poly(ethylene- <i>stat</i> -vinyl acetate) vs. poly(ethylene), see reverse					
Poly(ethylene- <i>stat</i> -vinyl acetate) vs. poly(vinyl acetate), see reverse					
Poly(ethylene- <i>stat</i> -vinyl acetate) vs. poly(ethylene <i>stat</i> -vinyl acetate)					
E/VAc (25 wt.% VAc) vs. E/VAc (12 wt.% VAc)	-	0.45	-	-	23
E/VAc (25 wt.% VAc) vs. E/VAc (17.7 wt.% VAc)	-	0.13	-	-	23
E/VAc (25 wt.% VAc) vs. E/VAc (38.7 wt.% VAc)	-	0.17	-	-	35
E/VAc (25 wt.% VAc) vs. E/VAc (50 wt.% VAc)	-	1.0	-	-	35
E/VAc (25 wt.% VAc) vs. E/VAc (75 wt.% VAc)	-	3.6	-	-	
3.1.5. POLY(ISOBUTENE) vs. OTHERS					7
Poly(isobutene) vs. poly(vinyl acetate)	9.9	7.3	6.3	0.020	82
Poly(isobutene) vs. poly(oxydimethylsilylene)	4.9	4.1	3.8	0.006	
3.1.6. POLY(PROPYLENE) vs. OTHERS					17
Poly(propylene) vs. poly(ethylene), see reverse					
Poly(propylene) vs. poly(styrene)					
Poly(propylene) vs. poly(oxydimethylsilylene)	3.2	2.9	2.8	0.002	
3.1.7. HALOGENATED HYDROCARBON POLYMERS vs. OTHERS					
Poly(chloroprene) vs. poly(ethylene), see reverse					2
Poly(chloroprene) vs. poly(<i>n</i> -butyl methacrylate)	2.2	1.5	1.3	0.0047	
Poly(chloroprene) vs. poly(styrene), see reverse					2
Poly(chloroprene) vs. poly(oxydimethylsilylene)	7.1	6.4	6.2	0.0050	
3.2. STYRENE POLYMERS vs. OTHERS					
Poly(styrene) vs. poly(ethylene), see reverse					2
Poly(styrene) vs. poly(chloroprene)	0.7	0.5	0.4	0.0014	46
Poly(styrene) vs. poly(methyl acrylate)	-	3.2	-	-	46
Poly(styrene) vs. poly(ethyl acrylate)	-	1.4	-	-	46
Poly(styrene) vs. poly(<i>n</i> -butyl acrylate)	-	1.4	-	-	46
Poly(styrene) vs. poly(2-chethylhexyl acrylate)	-	2.5	-	-	22
Poly(styrene) vs. poly(vinyl acetate)	4.2	3.7	3.4	0.0044	
Poly(styrene) vs. poly(methyl methacrylate)	3.2	1.5	0.8	0.013	101
Poly(styrene) vs. poly(oxydimethylsilylene)	-	-	1.3	-	8
Poly(styrene) vs. poly(oxydimethylsilylene)	6.1	6.1	6.1	~ 0	2
Poly(styrene) vs. poly(ethylene- <i>stat</i> -vinyl acetate), 17.7 wt.% VAc	1.8	2.8	3.2	-0.0074	2
Poly(styrene) vs. poly(ethylene- <i>stat</i> -vinyl acetate), 30.9 wt.% VAc	0.3	2.1	2.8	-0.0136	2
Poly(styrene) vs. poly(ethylene- <i>stat</i> -vinyl acetate), 38.7 wt.% VAc	2.3	2.0	1.9	0.0020	2
Poly(styrene) vs. poly(ethylene- <i>stat</i> -vinyl acetate), 26.6 wt.% VAc	3.3	2.6	2.3	0.0050	2
3.3. VINYL POLYMERS vs. OTHERS					
Poly(ethylene- <i>stat</i> -vinyl acetate) vs. poly(ethylene), see reverse					
Poly(ethylene- <i>stat</i> -vinyl acetate) vs. polystyrene, see reverse					
Poly(ethylene- <i>stat</i> -vinyl acetate) vs. self, see Hydrocarbon Polymers vs. Others					
3.3.1. POLY VINYL ACETATE vs. OTHERS					
Poly(vinyl acetate) vs. poly(isobutene), see reverse					
Poly(vinyl acetate) vs. poly(ethylene- <i>stat</i> -vinyl acetate), 12 wt.% VAc	-	8.3	-	-	
Poly(vinyl acetate) vs. poly(ethylene- <i>stat</i> -vinyl acetate), 17.7 wt.% VAc	-	7.5	-	-	
Poly(vinyl acetate) vs. poly(ethylene- <i>stat</i> -vinyl acetate), 26.6 wt.% VAc	6.3	5.8	5.5	0.0043	

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TABLE 3. cont'd

Polymer	Interfacial tension γ_{12} (mN/m \equiv dy/cm)			$-\frac{dy}{dT}$ (mN/m/K)	Ref.
	20°C	150°C	200°C		
Poly(vinyl acetate) vs. poly(ethylene-stat-vinyl acetate), 26.6 wt.% VAc	-	6.1	-	-	23
Poly(vinyl acetate) vs. poly(ethylene-stat-vinyl acetate), 30.9 wt.% VAc	-	5.6	-	-	23
Poly(vinyl acetate) vs. poly(ethylene-stat-vinyl acetate), 38.7 wt.% VAc	-	4.7	-	-	23
Poly(vinyl acetate) vs. poly(ethylene-stat-vinyl acetate), 50 wt.% VAc	-	3.5	-	35	35
Poly(vinyl acetate) vs. poly(ethylene-stat-vinyl acetate), 75 wt.% VAc	-	1.2	-	-	35
Poly(vinyl acetate) vs. poly(<i>n</i> -butyl methacrylate)	4.2	2.8	2.3	0.010	8
Poly(vinyl acetate) vs. poly(oxetetraethylmethylene)	5.5	4.5	4.1	0.0081	12
Poly(vinyl acetate) vs. poly(oxydimethylsilylene)	8.4	7.3	6.9	0.0081	2,12,82
Poly(vinyl acetate) vs. decane, C ₂₀ H ₄₄	7.1	4.6	3.6	0.0195	40
3.3.2. POLY(VINYL BUTYRATE) vs. OTHERS					
Poly(vinyl butyrate) vs. decane, C ₂₀ H ₄₄	1.9	0.9	0.5	0.0078	40
3.3.3. POLY(VINYL PROPIONATE) vs. OTHERS					
Poly(vinyl propionate) vs. decane, C ₂₀ H ₄₄	3.5	2.5	2.1	0.0080	40

3.4. ACRYLIC POLYMERS vs. OTHERS**3.4.1. POLY(METHYL ACRYLATE) vs. OTHERS**

Poly(methyl acrylate) vs. poly(ethylene), see reverse					
Poly(methyl acrylate) vs. poly(styrene), see reverse					
Poly(methyl acrylate) vs. poly(ethyl acrylate)	2.4	13	0.9	0.008	1,35,46
Poly(methyl acrylate) vs. poly(<i>n</i> -butyl acrylate)	4.0	3.0	2.6	0.008	1,35,46
Poly(methyl acrylate) vs. poly(2-ethylhexyl acrylate)	6.6	5.7	5.4	0.007	1,35,46

3.4.2. POLY(ETHYL ACRYLATE) vs. OTHERS

Poly(ethyl acrylate) vs. poly(ethylene), see reverse					
Poly(ethyl acrylate) vs. poly(styrene), see reverse					
Poly(ethyl acrylate) vs. poly(methyl acrylate), see reverse	2.1	1.3	1.0	0.006	1,35,46
Poly(ethyl acrylate) vs. poly(<i>n</i> -butyl acrylate)	3.9	3.2	3.0	0.005	1,35,46
Poly(ethyl acrylate) vs. poly(2-ethylhexyl acrylate)					

3.4.3. POLY(*n*-BUTYL ACRYLATE) vs. OTHERS

Poly(<i>n</i> -butyl acrylate) vs. poly(ethylene), see reverse					
Poly(<i>n</i> -butyl acrylate) vs. poly(styrene), see reverse					
Poly(<i>n</i> -butyl acrylate) vs. poly(methyl acrylate), see reverse					
Poly(<i>n</i> -butyl acrylate) vs. poly(ethyl acrylate), see reverse					
Poly(<i>n</i> -butyl acrylate) vs. poly(2-ethylhexyl acrylate),	1.8	1.2	1.0	0.005	1,35,46

3.4.4. POLY(2-ETHYLHEXYL ACRYLATE) vs. OTHERS

Poly(2-ethylhexyl acrylate) vs. poly(ethylene), see reverse					
Poly(2-ethylhexyl acrylate) vs. poly(styrene), see reverse					
Poly(2-ethylhexyl acrylate) vs. poly(methyl acrylate), see reverse					
Poly(2-ethylhexyl acrylate) vs. poly(ethyl acrylate), see reverse					
Poly(2-ethylhexyl acrylate) vs. poly(<i>n</i> -butyl acrylate), see reverse					

3.5. METHACRYLIC POLYMERS vs. OTHERS**3.5.1. POLY(METHYL METHACRYLATE) vs. OTHERS**

Poly(methyl methacrylate) vs. poly(ethylene), see reverse					
Poly(methyl methacrylate) vs. poly(styrene), see reverse					
Poly(methyl methacrylate) vs. poly(<i>n</i> -butyl methacrylate)	3.4	1.9	1.3	0.012	8
Poly(methyl methacrylate) vs. poly(<i>tert</i> -butyl methacrylate)	3.0	2.2	1.9	0.006	2

3.5.2. POLY(*n*-BUTYL METHACRYLATE) vs. OTHERS

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TABLE 3. cont'd

Polymer	Interfacial tension γ_{12} (mN/m \equiv dyn/cm)			$-\frac{d\gamma_{12}}{dT}$ (mN/m/K)	Refs.		
	20°C	150°C	200°C				
Poly(<i>n</i> -butyl methacrylate) vs. poly(chloroprene), see reverse							
Poly(<i>n</i> -butyl methacrylate) vs. poly(oxydimethylsilylene), see reverse							
3.5.3. POLY(<i>iso</i> -BUTYL METHACRYLATE) vs. OTHERS							
Poly(<i>iso</i> -butyl methacrylate) vs. poly(ethylene), see reverse							
3.5.4. POLY(<i>tert</i> -BUTYL METHACRYLATE) vs. OTHERS							
Poly(<i>t</i> -butyl methacrylate) vs. poly(ethylene), see reverse							
Poly(<i>t</i> -butyl methacrylate) vs. poly(oxydimethylsilylene), see reverse							
3.6. POLY(ETHERS) vs. OTHERS							
3.6.1. POLY(OXYETHYLENE) vs. OTHERS							
Poly(oxyethylene) vs. poly(ethylene), see reverse							
Poly(oxyethylene) vs. poly(ethylene-star-vinyl acetate), 25 wt.% VAc	6.4	5.8	5.5	0.0045	12		
Poly(oxyethylene) vs. poly(2-ethylhexyl, μ tylate)	6.6	4.8	4.1	0.014	107		
Poly(oxyethylene) vs. poly(<i>n</i> -butyl acrylate)	2.8	2.0	1.7	0.0055	107		
Poly(oxyethylene) vs. poly(oxytetramethylene)	4.5	3.8	3.6	0.0051	12		
Poly(oxyethylene) vs. poly(oxydimethylsilylene), see reverse							
Poly(oxyethylene) vs. eicosane, $C_{20}H_{42}$							
9.3 (90°C)							
0.040							
3.6.2. POLY(OXYTETRAMETHYLENE) vs. OTHERS							
Poly(oxytetramethylene) vs. poly(oxyethylene), see reverse							
Poly(oxytetramethylene) vs. poly(ethylene), see reverse							
Poly(oxytetramethylene) vs. poly(vinyl acetate), see reverse							
Poly(oxytetramethylene) vs. poly(ethylene-star-vinyl acetate), 25 wt.% VAc	1.5	1.2	1.1	0.0023	12		
Poly(oxytetramethylene) vs. poly(oxydimethylsiloxane), see reverse							
Poly(oxytetramethylene) vs. eicosane, $C_{20}H_{42}$							
1.1 (90°C)							
0.013							
3.7. POLY(ESTERS) vs. OTHERS							
Poly(oxyethylenoxyterephthaloyl) vs. polyethylene, see reverse							
Poly(oxyethylenoxyterephthaloyl) vs. poly(ethylene-star-propylene-star-hexadiene), see reverse							
Poly(oxytrimethyleneoxyisophthaloyl) vs. poly(ethylene), see reverse							
Poly(oxytetramethyleneoxyisophthaloyl) vs. poly(ethylene), see reverse							
Poly(oxyhexamethyleneoxyisophthaloyl) vs. poly(ethylene), see reverse							
Poly(oxyisophthaloyloxydecamethylene) vs. poly(ethylene), see reverse							
Poly(oxyisophthaloyloxydodecamethylene) vs. poly(ethylene), see reverse							
3.8. POLY(AMIDES) vs. OTHERS							
Poly(iminohexamethyleneimino adipoyl) vs. polyethylene, see reverse							
Poly(iminohexamethyleneimino adipoyl) vs. poly(ethylene-star-propylene-star-hexadiene), see reverse							
Poly(iminooxaphexamethylene) vs. poly(ethylene), see reverse							
3.9. EPOXY RESIN vs. OTHERS							
Epoxy resin vs. poly(butadiene), see reverse							
Epoxy resin vs. poly(butadiene-star-acrylonitrile), see reverse							
3.10. POLY(SILOXANES) vs. OTHERS							
Poly(oxydimethylsilylene) vs. poly(ethylene), see reverse							
Poly(oxydimethylsilylene) vs. poly(styrene), see reverse							
Poly(oxydimethylsilylene) vs. poly(propylene), see reverse							
Poly(oxydimethylsilylene) vs. poly(isobutene), see reverse							
Poly(oxydimethylsilylene) vs. poly(chloroprene), see reverse							
Poly(oxydimethylsilylene) vs. poly(vinyl acetate), see reverse							
Poly(oxydimethylsilylene) vs. poly(butadiene), see reverse							
Poly(oxydimethylsilylene) vs. poly(<i>n</i> -butyl methacrylate)	4.2	3.8	3.6	0.0037	2		
Poly(oxydimethylsilylene) vs. poly(<i>n</i> -butyl methacrylate)	3.6	3.3	3.2	0.0025	2		
Poly(oxydimethylsilylene) vs. poly(<i>n</i> -butyl methacrylate)	10.8	9.8	9.4	0.0078	12		
6.1							
6.2							

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TABLE 3. *cont'd*

Polymer	Interfacial tension γ_{12} (mN/m \equiv dyn/cm)			$-\frac{d\gamma_{12}}{dT}$ (mN/m/k)	Ref.
	20°C	150°C	200°C		
3.11. MISCELLANEOUS					
Eicosane ($C_{20}H_{42}$) vs. poly(oxyethylene), see reverse					
Eicosane ($C_{20}H_{42}$) vs. poly(oxytetramethylene), see reverse					
Eicosane ($C_{20}H_{42}$) vs. poly(vinyl acetate), see reverse					
Eicosane ($C_{20}H_{42}$) vs. poly(vinyl propionate), see reverse					
Eicosane ($C_{20}H_{42}$) vs. poly(vinyl butyrate), see reverse					
Eicosane ($C_{20}H_{42}$) vs. 1,3-propanediol 25 wt.% VAc	45.9	38.9 (90°C)	-	0.100	58
Eicosane ($C_{20}H_{42}$) vs. 1,4-butanediol	44.2	37.6 (90°C)	-	0.094	58
Eicosane ($C_{20}H_{42}$) vs. 1,5-pentanediol	41.6	36.7 (90°C)	-	0.070	58
Eicosane ($C_{20}H_{42}$) vs. 1,6-hexanediol	42.2	36.5 (90°C)	-	0.081	58
Eicosane ($C_{20}H_{42}$) vs. 1,10-decanediol	39.3	34.2 (90°C)	-	0.073	58

C. REFERENCES

1. S. Wu, "Polymer Interface and Adhesion", Marcel Dekker, New York, 1982.
2. S. Wu, *J. Polym. Sci. C*, **34**, 19 (1971).
3. S. Wu, *J. Adhesion*, **5**, 39 (1973).
4. T. Hata, T. Kasemura, in: L. H. Lee (Ed.), "Adhesion and Adsorption of Polymers", Vol. 12a, Plenum, New York, 1980, p. 15.
5. H. Schonhorn, G. L. Baker, F. S. Bates, *J. Polym. Sci., Polym. Phys. Ed.*, **23**, 1555 (1985).
6. L. H. Lee, *J. Polym. Sci. A-2*, **5**, 1103 (1967).
7. S. Wu, *J. Colloid Interface Sci.*, **31**, 153 (1969).
8. S. Wu, *J. Phys. Chem.*, **74**, 632 (1970).
9. S. Wu, *J. Macromol. Sci.*, **C10**, 1 (1974).
10. S. Wu, in: D. R. Paul, S. Newman, (Eds.), "Polymer Blends", Vol. 1, Academic, New York, 1978, p. 243.
11. R. J. Roe, *J. Phys. Chem.*, **72**, 2013 (1968).
12. R. J. Roe, *J. Colloid Interface Sci.*, **31**, 228 (1969).
13. T. Kasemura, N. Yamashita, K. Suzuki, T. Kondo, T. Hata, *Kobunshi Ronbunshu*, **35**, 263 (1978).
14. W. Berger, K. Olbricht, H. W. Kammer, *Faserforsch. Textiltech.*, **27** (1), 9 (1976); **27** (1), 15 (1976).
15. R. H. Detre, R. E. Johnson, Jr., *J. Colloid Interface Sci.*, **21**, 367 (1966).
16. H. Schonhorn, L. H. Sharpe, *J. Polym. Sci. A*, **3**, 569 (1965).
17. Y. Oda, T. Hata, *Preprints, 17th Annual Meeting High Polymer Society, Japan*, 1968, p. 167.
18. Y. Oda, T. Hata, *Preprints, Sixth Symp. Adhesion and Adhesives, The Adhesion Society of Japan*, 1968, p. 69.
19. W. H. Smarook, S. Bonotto, *Polym. Eng. Sci.*, **8**, 41 (1968).
20. S. Wu, *Polym. Eng. Sci.*, **27**, 335 (1987).
21. T. Hata, *Kobunshi*, **17**, 594 (1968).
22. T. Hata, *Hyomen*, **6**, 659 (1968).
23. U. Uraki, T. Hata, *Preprints, Thirteenth Symp. Adhesion and Adhesives, The Adhesion Society of Japan*, 1975.
24. Y. Kitazaki, H. Yamada, T. Hata, *Preprints, Ninth Symp.*

References VI / 541

48. J. N. Roitman, A. G. Pittman, *Polym. Lett.*, **10**, 499 (1972).
49. H. W. Fox, W. A. Zisman, *J. Colloid Sci.*, **7**, 428 (1952).
50. M. K. Bennett, W. A. Zisman, *J. Phys. Chem.*, **66**, 1207 (1962).
51. V. L. Gott, R. E. Baier, Public Document PH43-68-84-4-2, National Technical Information Service, Springfield, Virginia, 22151, May 1973.
52. D. H. Kaelble, J. Moacanin, *Polymer*, **18**, 473 (1977).
53. M. K. Bennett, H. Ravener, *J. Adhesion*, **9**, 157 (1978).
54. D. H. Kaelble, "Physical Chemistry of Adhesion", Wiley, New York, 1971.
55. A. G. Pittman, in: L. A. Wall (Ed.), "Fluoropolymers", Vol. 25, Wiley, New York, 1972, p. 419.
56. R. N. King, J. D. Andrade, S. M. Ma, D. H. Gregonis, L. R. Brosnion, *J. Colloid Interface Sci.*, **103**, 62 (1985).
57. A. K. Rastogi, L. E. St. Pierre, *J. Colloid Interface Sci.*, **31**, 168 (1969).
58. T. Kasemura, N. Yamashita, K. Suzuki, T. Kondo, T. Hata, *Kobunshi Ronbunshu*, **35**, 213 (1978).
59. G. W. Bender, D. G. LeGrand, G. L. Gaines, Jr., *Macromol.*, **2**, 681 (1969).
60. A. K. Rastogi, L. E. St. Pierre, *J. Colloid Interface Sci.*, **35**, 16 (1971).
61. T. Kasemura, T. Hata, *Kobunshi Ronbunshu*, **33**, 192 (1976).
62. T. Kasemura, K. Suzuki, F. Uzi, T. Kondo, T. Hata, *Kobunshi Ronbunshu*, **35**, 779 (1978).
63. T. C. Kendrick, B. M. Kingston, N. C. Lynd, M. J. Owen, *J. Colloid Interface Sci.*, **24**, 135 (1967).
64. H. T. Patterson, K. H. Hu, T. H. Grindstaff, *J. Polym. Sci. C*, **34**, 31 (1971).
65. R. E. Baier, "Surface Properties of Materials for Prosthetic Implants", Calspan Corporation, CAL Report VH-2801-p-2, February 1970.
66. A. Herczeg, G. S. Ronay, W. C. Simpson, *Proc. Nat. Soc. Aerospace Med. Proc. Eng. Conf.*, Dallas, Texas, **2**, 221 (1970).
67. L. H. Sharpe, H. Schonhorn, *Adv. Chem. Ser.*, **43**, 189 (1964).
68. R. T. Foister, *J. Colloid Interface Sci.*, **99**, 568 (1984).
69. L. S. Penn, E. R. Bowler, *Surface Interface Anal.*, **3** (4), 161 (1981).
70. J. T. Koberstein, Chemical Engineering Department, Princeton University, Princeton, New Jersey, Private Communication, 1986.
71. T. Fort Jr., *Adv. Chem. Ser.*, **43**, 302 (1964).
72. R. J. Hybart, T. R. White, *J. Appl. Polym. Sci.*, **3**, 118 (1960).
73. E. Nyilas, W. A. Morton, R. D. Cumming, D. M. Lederman, T. H. Chiu, *Polym. Preprints, Am. Chem. Soc.*, **16** (2), 165 (1975).
74. L. S. Penn, T. K. Liao, *Composites Technol. Rev.*, **6** (3), 133 (1984).
75. M. Hayashi, R. Katou, T. Sakai, *Seni Gakkaishi*, **38** (4), T-147 (1982).
76. R. Sacher, *J. Appl. Polym. Sci.*, **22**, 2137 (1978).
77. M. Litt, J. Herz, *J. Colloid Interface Sci.*, **31**, 248 (1969).
78. M. Litt, J. Herz, *Polym. Preprints, Am. Chem. Soc.*, **10**, 905 (1969).
80. H. W. Fox, P. W. Taylor, W. A. Zisman, *Ind. Eng. Chem.*, **39**, 1401 (1947).
81. D. G. LeGrand, G. L. Gaines, Jr., *J. Polym. Sci. C*, **34**, 45 (1971); *J. Colloid Interface Sci.*, **50**, 272 (1975).
82. Y. Kirazaki, T. Hata, *Preprints, 18th Annual Meeting High Polymer Society Japan*, 1969, p. 478.
83. Q. S. Bhatia, J. K. Chen, J. T. Koberstein, J. E. Sohn, J. A. Emerson, *J. Colloid Interface Sci.*, **106**, 353 (1985).
84. B. R. Ray, J. R. Anderson, J. J. Schatz, *J. Phys. Chem.*, **62**, 1220 (1958).
85. J. E. Sohn, J. A. Emerson, J. K. Chen, A. F. Siegel, J. T. Koberstein, *Preprints, Polym. Mater. Sci. Eng., Am. Chem. Soc.*, **49**, 447 (1983).
86. P. Luner, M. Sandell, *J. Polym. Sci. C*, **28**, 115 (1969).
87. W. C. Hamilton, *J. Colloid Interface Sci.*, **40**, 219 (1972).
88. H. J. Busscher, J. Arends, *J. Colloid Interface Sci.*, **81**, 7 (1981).
89. B. R. Ray, W. L. Wasley, J. J. Schatz, *J. Phys. Chem.*, **61**, 1220 (1957).
90. H. D. Feltman, J. R. McPhie, *Textile Res. J.*, **34**, 63 (1964).
91. R. E. Baier, C. Akers, S. Perlmutter, V. L. Gott, J. O'Riordan, Calspan Report WO6-EB-5307-M-18, National Institute of Health, Maryland, March 1976.
92. R. E. Baier, W. A. Zisman, *Macromol.*, **3**, 70 (1970).
93. V. R. Gray, in "Wetting", The Society of Chemical Industry Monograph No. 25, London, 1967, p. 99.
94. S. Wu, *J. Colloid Interface Sci.*, **71**, 605 (1979); **73**, 51 (1980).
95. J. F. Paday, *Proc. 2nd Intern. Congr. Surface Activity*, 136 (1937).
96. E. Chibowski, B. Bilinski, A. Wuksmundzki, W. Wojcik, *Colloid Interface Sci.*, **86**, 559 (1982).
97. R. Fanelli, *J. Am. Chem. Soc.*, **72**, 4016 (1950).
98. T. Kasemura, T. Kondo, T. Hata, *Kobunshi Ronbunshu*, **35**, 815 (1979).
99. S. Wu, K. J. Brzozowski, *J. Colloid Interface Sci.*, **37**, 1 (1971).
100. T. Kasemura, N. Yamashita, T. Hata, *Kobunshi Ronbunshu*, **33**, 703 (1976).
101. M. Toyama, T. Ito, *Polym.-Plast. Technol. Eng.*, **2** (2), (1973).
102. J. J. Kasper, E. V. Kring, *J. Phys. Chem.*, **59**, 1019 (1955); J. J. Jasper, B. R. Kerr, F. Gregorich, *J. Am. Chem. Soc.*, **75**, 5252 (1953).
103. S. H. Anastasiadis, J. K. Chen, J. T. Koberstein, J. E. Sohn, J. A. Emerson, *Polym. Eng. Sci.*, **26**, 1410 (1986).
104. O. R. Quayle, *Chem. Rev.*, **53**, 439 (1953).
105. D. W. van Krevelen, "Properties of Polymers", Elsevier, Amsterdam, 1976.
106. J. J. Elmendorp, O. de Vos, *Polym. Eng. Sci.*, **26**, 415 (1986).
107. T. Kasemura, M. Inagaki, T. Hata, *Kobunshi Ronbunshu*, **35**, 131 (1978).
108. F. M. Fowkes, in "Chemistry and Physics of Interfaces", American Chemical Society, Washington DC, 1968, p. 109.
109. D. K. Owens and R. C. Wendt, *J. Appl. Polym. Sci.*, **13**, 1 (1969).